E/CONF.39/A/65
3 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A. 4. 2. 3

United Arab Republic

# DEVELOPMENT OF THE PETROLEUM INDUSTRY IN THE UNITED ARAB REPUBLIC

By A. MUSTAFA, D. Sc.,
Cairo University,

I. K. ABDO, Ph. D.,
National Research Centre

M. BORHAM, Ph. D.,
General Petroleum Corp.

and F. M. EBEID, Ph. D.,
National Research Centre

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

No.423 DEVELOPMENT OF THE PETROLEUM INDUSTRY

A.4.2.3. IN THE UNITED ARAB REPUBLIC

by A. MUSTAFA, D.Sc., Cairo University
I.K. ABDO, Ph. D., National Research Centre
M. BORHAM, Ph. D., General Petroleum Corp.
F.M. EBEID, Ph. D., National Research Centre

1. Marked progress had been achieved in the petroleum industry of the UAR during the last decade, a fact which resulted in an increase of 12 million pounds in the national income in the year 1960 as compared to the year 1952. The authors will try to illustrate the development in various branches of the industry, with special emphasis on the methods, adopted and/or under consideration for the full utilisation of local crude oils to satisfy the country's needs from different petroleum fractions, and petrochemical raw materials and finished products.

## Exploration and Production.

2. Although the UAR was one of the oldest oil-producing countries in the world, yet, up to 1951 there were only four producing fields. During the last decade, seven oil fields were newly discovered, making a total of eleven. Intensive geological exploration is being carried out, applying up-to-date methods. Marine geophysical techniques have also been recently introduced. The expansion in the drilling activity could be represented by the rise in number of drilling units from one unit in 1952 to 14 units in 1961, including turbo-drillers. As a result, crude oil production has increased from 2.5 million cubic meters in 1951 to 4.2 million cubic meters in 1961.

## Characteristics of Crude Oils.

3. Indigenous crude oils are of the mixed-base or intermediate type, generally characterised by their low percentage yield of distillates, and high contents of sulphur, resinous materials, and asphaltic residues. Table I shows the general characteristics of the main crudes of the UAR.

## Processing.

4. The crude processed in local refineries has increased from 2.5 million metric tons in 1951 to about 5.0 million metric tons in 1961. The major units in standing refineries include atmospheric and vacuum distillation, thermal reforming, asphalt blowing, hydrogen sulphide separation and sulphur production, and conventional treating equipment.

Production and Consumption Picture.

5. Table II represents the % yields of different fractions which could be obtained from local crudes under the present processing conditions. These figures are based on the production of mazout with a maximum Redwood N° 1 viscosity of 2000 seconds at 100°F. Table III represents, on the other hand, a comparison of the consumption picture in 1951 with that in 1961.

6. It could be easily noted from tables II and III, that, processing of local crudes in the existing refineries should lead to a surplus in gasoline and mazout, and a serious shortage in middle distillates. At present, the situation is being remedied by exporting part of our heavy crudes, and importation of crudes rich in middle distillates.

Projects under the Five-Year Plan.
Suez Refinery Expansion.

7. In order to balance the production and comsumption rates and attain self-sufficiency of almost all petroleum products, a new refinery is under erection in Suez, with a crude oil capacity of 2.0 million metric tons. The first units will be on stream in late 1963. This refinery expansion is primarily for the production of distillate fuels. These are Kerosene, gas oil, and diesel fuels. Other petroleum products are propane, butane, light naphtha, gasolene, fuel oil, coke, and fuel gas. Petrochemical products are sulphur, benzine and/or toluene, and dodecy/benzine.

8. The new facilities are designed to process 5,000 MT/SD of Skimmed Balayim crude, 370 MT/SD of lube oil plant asphalt, and 1430 MT/SD of a 50/50 mixture of Arabian and Balayim naphthas. A delayed coking unit will charge Balayim residue, after atmospheric and flash distillation, to remove gasoline and middle distillates consequently. Products from this unit will include gases, gasoline, middle distillates, and coke.

9. In order to improve the quality of gasoline, a catalytic reforming unit will be included. Coker gasoline, in combination with straight run gasoline from other standing units, will be first fractionated to yield a light naphtha cut with a 160° Fend point (for use as feed stock in the manufacture of petrochemical starting materials via steam pyrolysis). The heavy naphtha, after being desulphurised, represents the feed for the catalytic reformer. The main product will be a stabilized reformate having a 100 octane number, clear (by the Research Method).

10. Hydrogen, as a by-product from the reformer, will be utilized for hydrofining virgin middle distillates. A second hydrofining unit will be used for stabilizing, and desuphurising the coker middle distillate fraction. Additional hydrogen requirements for this unit will be satisfied by steam-reforming of light gases ($C_1$ and $C_2$). The final kerosene, gas oil, and diesel oil fractions will have 0.02, and 0.25, and 0.50% by weight sulphur contents, respectively.

11. The different gas streams, after fractionation, and Hydrogen sulphide removal (through ethanolamine extraction and alkali

treating), will be distributed to the following sections: Hydrogen Production Plant, Dodecylbenzine Plant, Sulphur production plant, and Butagas bottling section. Surplus light gases ($C_1$4 $C_2$) will be fed to a neighbouring fertilizer plant, and partly used as fuel.

12; At the present time, the country depends completely on importation to satisfy it's needs from benzol and toluene. Hence, a Udex extraction unit will be incorporated to separate benzol and/or toluene from suitable reformate fractions.Part of the benzol product will be utilized for the production of dodecylbenzene. The plant will include a tetramer unit, and a dodecylbenzene production unit. The erection of this plant is expected to considerably ease up the situation with regard to the consumption of edible oils and fats in soap manufacturing industries.

13. Most of the coke product from the coking unit will find use as fuel in a steam-raising power-station. Active research is being carried out to improve the quality of this coke,and/or to find other fields of application.

Production of Lubricating oil Base Stocks.

14. A lubricating oil plant, with a capacity of 60.000 metric tons/year, will be on stream in 1964. This plant will include atmospheric and vacuum distillation, propane deasphalting, phenol extraction, solvent dewaxing, vacuum rerunning, absorption filtration , and blending and compounding units. Wax treating and moulding units will be also included, for the production of paraffin wax. Table IV summarizes the estimated production of petroleum fractions, and petrochemical raw materials and products in 1964.

Petrochemicals.

15. A project for the production of petrochemicals is presently under study.The surplus light naphtha,and hydrocarbon gases from the coking complex will form the starting material, for the production of the following petrochemicals:

| | |
|---|---|
| Polyethylene | 10,000 T/Y |
| Polyvinylchloride | 10,000 T/Y |
| Synthetic rubber | 8,000 T/Y |
| Polyacrylonitrile | 5,000 T/Y |
| Methanol | 4,000 T/Y |
| Benzol hexachloride | 1,800 T/Y |
| Phenol | 6,600 T/Y |
| Caprolactam | 3,000 T/Y |
| Calcium nitrate, 15.5 % N | 458,000 T/Y |
| Calcium ammonium nitrate,20.5%N | 212,000 T/Y |

Technical and economic studies are under way to select the most suitable methods, and it is expected that this project will be executed in the next few years.

Research.

16. A thorough study of the chemical nature of local crude oils is in progress.This includes the study of the distribution of

hydrocarbon types, sulphur and nitrogen compounds, and metallic constituents throughout the whole boiling range of each crude, as well as the resinuous fraction and asphaltic residues. Such studies are a prerequisite to the successful processing of any crude.

17. In Balayim crude oil, it has been found that the aromatic nature increases sharply from gasoline to Kerosene , and goes up with rising boiling point. As regards the sulphur compounds, it has been established that the major fraction of sulphur compound types in Balayim distillates is represented by sulphides and thiophenes, while the mercaptan and disulphide sulphur contents are negligible. The nitrogen contents of U.A.R. crudes differ widely from field to field, and amounts to 1.25% by weight in some instances. The realization of the serious effect of certain types of nitrogen compounds upon the performance of catalysts, and the storage stability of petroleum products, has initiated research activities in the field of nitrogen type analysis.

18. As an alternative to the coking process, hydrocracking of the whole crude is under intensive study. Batch-scale experiments show marked differences between various catalysts as regards the yield of liquid products and their fractional compositions, the % Hydrogen consumption, and the rates of desulphurisation and denitrogenation reactions.

19. Balayim and Ras-Gharib crude oils contain vanadium, and nickel in the range of 150, and 100 p.p.m. consequently. These figures are relatively high when compared with those of other crude oils produced in other Middle-East areas. The problem presented by the large production of straight run gasoline has focussed attention on investigations in the field of catalytic reforming of local gasolines for the production of aromatics; benzene, toluene, or zylenes. Production of benzene, for example, from a 65-86°c fraction of Gharib gasoline, was investigated. This fraction was found to contain 27.1 volume % methylcyclopentane and 20.4 % cyclohexane. Catalytic reforming of this fraction under optimum operating conditions produced benzene 89.5% yield of theoretical.

20. Other topics of research include:
    (a) Reforming of wide boiling range naphthas,
    (b) Isomerisation of the $C_5$-$C_6$ fraction of gasoline,
    (c) Oxidation of paraffin wax,
    (d) Production of lubricating oil base stocks from local crudes,
    (e) Production of pure ring compounds from petroleum,
    (f) Effect of gamma irradiation on the use properties of lubricating oil base stocks,
    (g) Utilisation of local clays as catalysts, and/or as catalyst carriers, or in adsorbent refining. Success has already been attained in this application whereby local clays will be used for the adsorbent refining of light and medium lube oil cuts in the projected lube oil plant.

Petroleum Research Centre.

21. A new petroleum research centre will be established in the near future. This centre will be concerned with local problems connected with the refining, transportion, and utilization of crude oil and all petroleum products. Fields of investigations will cover petroleum geology, production, chemistry, refining, petrochemicals, economics, as well as pilot plant studies.

Arab Petroleum Congress.

22. Since 1959, a petroleum congress had been annually held in one or the other of the Arab Countries, under the auspices of the Arab League. Non-member countries, as well as representatives of oil companies, are also invited to participate. Under its agenda, problems in the fields of oil geology, exploration, production, chemistry, processing, transport and economy are being discussed.

23. To conclude, it does not fail us to point out that full international cooperation has been a significant factor in the development of the petroleum industry in the U.A.R. The progress already achieved is a living example of the blessings of such cooperation between the highly developed, and the developing countries.

TABLE I

PHYSICAL CHARACTERISTICS OF MAIN UAR CRUDE OILS

| Characteristic | Balayim | Ras Gharib | Rudeis Sudri | Ras Bakr | Sudr |
|---|---|---|---|---|---|
| A P I gravity | 22.14 | 24.85 | 24.68 | 21.47 | 22.67 |
| Water content, % by volume | 0.20 | 0.20 | 0.05 | 0.10 | 0.15 |
| Salt content, % by weight | 0.020 | 0.015 | 0.002 | 0.016 | 0.005 |
| Pour point, of | 30 | 30 | 40 | 30 | 30 |
| Viscosity, Red.1 at 100°F | 300 | 110 | 180 | 617 | 266 |
| R.V.P., p.s.i: | 4.8 | 4.4 | 4.0 | 2.8 | 1.3 |
| Sulphur content, % by weight | 2.8 | 2.95 | 2.1 | 4.5 | 1.9 |
| Conradson Carbon Content | 10.5 | 8.5 | 10.0 | 10.3 | 9.7 |
| Engler Distillation: | | | | | |
| I.B pt, C° | 75 | 68 | 58 | 75 | 111 |
| % recovery to 100°C | 4.0 | 4.0 | 6.0 | 3.0 | -- |
| 125°C | 7.0 | 7.5 | 10.0 | 5.0 | 2.5 |
| 150°C | 10.5 | 11.5 | 14.0 | 8.5 | 6.0 |
| 175°C | 14.0 | 15.5 | 18.0 | 12.0 | 9.0 |
| 200°C | 17.0 | 19.0 | 22.0 | 14.5 | 13.0 |
| 225°C | 20.0 | 23.0 | 26.0 | 18.0 | 16.0 |
| 250°C | 23.5 | 26.5 | 30.0 | 22.0 | 20.5 |
| 275°C | 27.5 | 31.0 | 34.0 | 26.0 | 24.5 |
| 300°C | 32.0 | 35.0 | 38.0 | 30.0 | 28.0 |
| Ash content, % by weight | 0.06 | 0.028 | -- | 0.035 | 0.032 |

TABLE II

% REFINERY DISTILLATION YIELDS FROM U.A.R. CRUDE OILS

| Product | Balayim | Ras Gharib | Ras Bakr | Sudr |
|---|---|---|---|---|
| Light Gases | 6.78 | 1.07 | 0.39 | 0.65 |
| Butagas | 0.18 | 0.61 | 0.25 | 0.38 |
| Gasoline | 6.72 | 8.93 | 7.80 | 2.63 |
| kerosene | ---- | 5.56 | ---- | 8.74 |
| Gas Oil | ---- | 2.78 | ---- | 1.22 |
| Diesel Oil | ---- | 3.51 | ---- | ---- |
| Mazout | 86.94 | 72.13 | 86.36 | 80.99 |
| Fuel gas | 3.00 | 3.00 | 3.00 | 3.00 |
| Loss | 2.38 | 2.41 | 2.20 | 2.39 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

TABLE III

COMPARISON OF CONSUMPTION FIGURES IN 1951 and 1961

| Product | 1951 | | 1961 | |
|---|---|---|---|---|
| | metric tons | % of total | metric tons | % of total |
| Light gases for fertilizer plant | ---- | ---- | 30.000 | 0.7 |
| Butane | 2,900 | 0.1 | 25,000 | 0.5 |
| Gasoline | 265,000 | 8.6 | 253,000 | 5.6 |
| Kerosene | 631,000 | 20.6 | 756,000 | 16.6 |
| Gas oil | 200,000 | 6.5 | 634,000 | 13.9 |
| Diesel oil | 178,000 | 5.8 | 253,000 | 5.1 |
| Mazout | 1,701,000 | 55.6 | 2,440,000 | 53,4 |
| Lubricants and greases | 40,000 | 1.3 | 55.000 | 1.2 |
| Bitument and Cut backs | 45,000 | 1.5 | 118,000 | 2.5 |
| Total | 3,062,900 | 100.00 | 4,564.000 | 100.00 |

TABLE IV

ESTIMATED REFINERY'S PRODUCTION IN 1964

| Product | Production in metric tons |
|---|---|
| Light gases | 85,000 |
| Propane | 46,000 |
| Butane | 67,000 |
| Light naphtha | 120,000 |
| Gasoline, 100 O.N. | 156,000 |
| Gasoline, 85 O.N. | 275,000 |
| Kerosene | 830,000 |
| Solar | 472,000 |
| Diesel | 337,000 |
| Mazout | 2,893,000 |
| Asphalt | 155,000 |
| Sulphur | 30,000 |
| Lube oil base stocks | 60,000 |
| Greases | 9,000 |
| Paraffin wax | 6,400 |
| Benzol | 3,000 |
| Dodecylbenzene | 6,000 |
| Coke | 382,000 |
| Fuel gases and loss | 512,000 |
| Total | 6,445,000 |

423 E - Oct. 1962 - 1,600

E/CONF.39/A/66
3 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.1

Finland

# MINING DEVELOPMENT POLICY

By Herman STIGZELIUS,
Director of Bureau of Mines,
Ministry of Commerce and Industry,
Finland

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

# Mining Development Policy

by

Herman Stigzelius,

Director of Bureau of Mines,
Ministry of Commerce and Industry, Finland

## 1. The formulation of a national mining policy.

(a) General

Multiform industrial activity requires access to raw materials, trained labour power, communication facilities, water and power, as well as sufficient sales possibilities for the products of industry. In an under-developed country, the possibilities for rapid industrial expansion are often meagre and, in order to lead the development in the right direction, it is necessary to make careful investigations of existing resources and to utilize them so that new qualifications toward gradual advancement of livelihood are acquired.

Among the first steps in the development of industry are investigation, exploitation and export of ore, minerals and other raw materials existing in the country. In case these can be sold on the world market at prices allowing a profitable return, there is even economic justification for further development of the raw material industry in question, as well as communication facilities, power procurement, institutes of learning etc. By these means further pre-conditions are acquired for a wider and multiform progress of the country's livelihood.

Exploitation of the country's mineral resources does not have to signify draining the country of its mineral reserves. Actually a profitable and well designed management of mining tends to increase the known accesses. Expansive mining requires intense prospecting and continuous inventories of known resources, whereby new reserves often

compensating many times over the used quantities of ore may be encountered. On the contrary we can consider that a known ore which has not become an object of mining is being preserved as a national reserve. As the ore is not worked, no further investigations of it nor of eventual corresponding findings are carried out the known ore reserve cannot increase.

At the beginning of its industrial evolution, a country often finds that its ore and other raw materials are exported in a more or less unrefined state. The next step on the road of progress is the building of a refining industry for these raw materials. This procedure can and ought to be executed as soon as the accesses to raw material have been secured and it is technically and economically possible to carry out plans for further refining. This often necessitates that the country has good technical knowledge and communication facilities and that it is respected as a commercial partner on the international market.

(b) Mining legislation

The construction of modern mining involves huge investments which even in the most positive cases create profit only after several years of constant exertion, and the risk of unpredictable losses is always of significance in mining.

In order that the capital which is needed for the development of a country's mining industry may find its way into the state, it is important that legislated order prevails in the country as well as political and economic stability and also that legislation favours enterprise in regard to taxes, freight, customs, duties, fees and other burdens. Low taxes and respective payment obligations are undoubtedly active promoters of every kind of industrial activity.

Particular emphasis should be attributed to the forming of mining legislation, which essentially can promote, but also smother interest for prospecting activity and building of the mining industry in general. As a rule it can be said that concession procedure is best adaptable to searching for and exploitation of extensive layer-formed findings such as oil, coal etc., while free claim right has a strongly stimulating effect on prospecting activity within areas which hold intrusive and eruptive rock formations, where ore bodies of more limited quantities can be expected to exist. A state's monopoly for utilizing mineral resources usually is justified only when the state itself is capable of pursuing intense prospecting activity and even of making the investments the building of mining industry requires.

which is seldom the case in under-developed countries.

(c) Relations to foreign enterprises.

It is desirable that under-developed countries welcome foreign capital and expert knowledge into the country. It is appropriate to codify the mining legislation with stipulations that foreigners may be granted a right to practice prospecting and mining only on conditions imposed upon them by the state, each case to be dealt with separately. These conditions must not be so strict as to frighten off sound enterprising spirit, although they should comply with the essential national interests.

(d) Cooperation among under-developed countries.

Many under-developed countries, especially among the relatively new ones, spurred by momentous national feeling, often endeavour to build a multiform refining industry very rapidly very often on the basis of insufficient resources. For example, an iron ore strike is not adequate grounds for building an iron and steel plant. A lack of coking coal resources is not economically compensated by the possibility of making charcoal from the wood material in the jungle. The lack of power procurement, communication facilities and professional skill can not be eliminated in one jump. Also the sales possibilities at competitive prices of the products of the proposed plant should be sufficiently planned before realizing all too grand-scale industrialization plans.

Possibilities of rapid industrialization are greatly increased through economic and technical collaboration among countries within the same geographical area. Let us for example assume that A has iron ore and B has coking coal resources. By way of mutual exertion, it might be possible to establish a steel works with the ability to compete and to answer the mutual consumption of certain steel products of these countries, while the same plan, executed within the narrow national boundaries, would prove a fiasco and become a burden to the livelihood of both countries.

2. Organization of national mining services.

(a) Bureau of mines

For the scheming of a suitable mining policy, for the preparation of matters concerning it, for the management of the administration of mining and for seeing that regulations are observed, every country should have special personnel, sufficiently competent and with sufficient authority. Matters concerned hereby could well be

adjoined in a mining bureau, which, for example, can be incoporated administratively in the ministry in charge of industrial matters.

(b) Geological survey.

The knowledge of the geological structure and the mineral resources of a country is the basis on which the mining activity can be built. The better knowledge is the better are the pre-conditions for appropriate planning of the natural lines development of mining. Thus, one of the first assignments to be carried out is the overall geological mapping of the country. As it is for public welfare, it is appropriate that such a mapping be carried out by the state and for this end, it is advisable to establish a state-administered geological survey.

As regards the geological mapping, it is appropriate to utilize in large measure the possibilities offered by flight photography and aero-geophysical mapping to obtain a survey of the general structure and extent of different geological formations. With a minimum of time and expensive field work, such a flight mapping can give an initial picture of the geological structure of the country, which can and should, later, be completed by continuous explorations in ever smaller detail by means of field work.

The geological survey should, in collaboration with the mining bureau and the mining industry, cooperate in the mapping, investigation and estimation of the country's raw material resources. To this end, the survey should, within economic possibilities, be provided with geophysical ore searching apparatus, diamond drills, mineralogical and chemical laboratories among other things, and of course, with sufficient trained personnel.

(c) Training of mining engingeers, geologists and supporting technicians.

In most under-developed countries the lack of trained personnel presents a serious hindrance to the rapid development of mining. This holds true for mining engineers as well as geologists and technical, social and administrative personnel for the diversified duties involved in a developed industrial activity.

Competent schooling of mining engineers and geologists should be considered a matter of major importance in countries where possibilities exist for building a mining industry. They should endeavour to set up a mining technical faculty within a technical university, with possibilities for specializing in geology, prospecting, mining, ore dressing and metallurgy. However, this cannot

often be carried out rapidly in under-developed countries. The lack of competent instructors may partially be compensated by hiring foreign experts and partially by training talented students at foreign technical colleges and research institutes, so as to be competent to take charge of instruction in their professional subjects as soon as possible. An intimate, plamned cooperation with some well-organized university in a more developed country would be of great assistance. In order that the young men who have received good foreign training should devote themselves to university teaching, it is of course necessary that they be paid satisfactorily. Underpayment of university teachers and higher governmental employees in general is unfortunately characteristic of many under-developed countries.

A hindrance to effective higher technical and scientific training, apart from the lack of teachers, is also the paucity of pupils with satisfactory basic school education. This lack cannot, however, be atoned for until the whole school system has been brought up to the level of modern requirements in general literacy among the great mass of the people and possibilities for further education of talented youth exist. The elevation of the general education level in an underdeveloped country is a gigantic project which requires time as well as money, but it is a goal that is worth the exertion, and, in the long run, the only chance of elevating the country from its state of under-development.

A third hindrance to the effective training of competent mining engineers and geologists is the lack of economic resources for building instruction precints and laboratories, for procuring laboratory equipment and other instruction material as well as payments and scholarships. In countries where there is an unavoidable demand for arranging this instruction and where the other qualifications exist for the development of university instruction, these economic factors, however, must not be allowed to reverse the decision. The means should be secured by the state or begged from organizations and countries having an interest in the development of the country.

Besides mining engineers and geologists, an expansive mining industry also requires professional workers with lower technical training. The arranging of a systematic schooling for such supporting technicians in special technical schools can be effected after the higher instruction has been developed, teachers are available and mining has reached a certain stage of development. Until then it is

necessary to make foremen and lower technical personnel of labourers who, by way of experience and application, have earned a position of more responsibility.

Attempts should be made to arrange for systematic professional schooling of professional workers within mining.

(d) Technical research.

For studying and developing possibilities, for the most economic utilization of the country's mineral resources, for the refining of the same and for the preparation of possibilities of technical research for advanced students and researchers, it would be necessary to study the possibilities of establishing a metallurgical laboratory, in which ore dressing and other metallurgical work could be carried out. Executed by the state, the easiest means in most under-developed countries, such a laboratory could administratively be subordinated to the governmental bureau of mines and should be in close collaboration with the geological survey as well as with the eventual mining faculty at the university. Alternatively the laboratory could be contained in one of these organs or eventually form a department within a technical research institute with multiform activity. In any case it must be stated that the organization of "national mining services" cannot be completed before the state and other interested parties have available a well equipped metallurgical research laboratory under competent management.

3. State-owned mining enterprises

In many under-developed countries as well as more advanced ones, there is often a powerful national interest to develop mining under administration of the state. How to adapt the activity to governmental administration is a problem of great momentum. In countries with free enterprising it can generally be recommended that governmental enterprise should be in the form of a stock company, in which the state and other administrative organs hold the majority of the stock, and are fully equalized in their activity by other mining enterprises. Thus the management of the enterprise is forced to strive for the best possible economic result. They are not allowed to pursue any kind of unprofitable activity with regard to public interest, unless the state provides funds for them. Through the stock holders' meeting, in which the state prevails, the company management is responsible for the activity of

the enterprise and, in all respects, the activities of the corporation are bound by stock company stipulations and good business conduct. If such an administratively organized enterprise continously works at a loss, its activity should be discontinued or reorganized.

551 E - Oct. 1962 - 1,600

E/CONF.39/A/67
3 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.1

Finland

# ON THE POSSIBILITIES OF PROSPECTING FOR ORES IN SIERRA LEONE

By V. MARMO,
Professor,
University of Helsinki,
Director of Geological Survey,
Finland

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

## On the possibilities of prospecting for ores in Sierra Leone

b. 554

by

V. Marmo , Professor,
A. 5.2.1. University of Helsinki, Director of
Geological Survey, Finland.

### 1. Geological aspects

Modern prospecting and exploration of ores requires as accurate a knowledge of the geology of the area to be prospected as possible. Therefore it is important to begin by discussing the stage of the geological survey of the country.

The necessary geological work, as well as the particular data required for the ore prospecting, on the other hand, must depend upon the general geology of the country.

The geological basement of Sierra Leone is Precambrian. Thus it belongs to the oldest formations of the globe. In this sense it has very much in common with similar Precambrian basements of, for instance, Canada and Finland. In such an environment,particular ore types are to be expected, and a geological mapping on a petrological basis is much more important than a stratigraphical differentiation of formations, as was the case when some older geological maps were made.

In Sierra Leone, there are several "schist belts" and areas which may be promising from the point of view of ore prospecting. Those in the Central part of the country have already been mapped in such way that the petrological requirements set forth above are fullfilled[1] and there the geological survey necessary for the ore

- - - - - - - -

1) Wilson, N.W.-Marmo, V., Geology, geomorphology and mineral resources of the Sula Mountains; Geol. Surv. Sierra Leone, Bull. n:o 1, Sierra Leone (1958).
Marmo, V.,Geology of the Kangari Hills and of the area W of Mamansu: -Geol. Surv. Sierra Leone, Bull. n:o 2,(1962).

prospecting already exists. The major part of the country,however, still awaits this kind of survey, with the exception of the so called "Colony complex" on the Atlantic shore and the Gola forest on the Liberian frontier, which to the knowledge of the present author have been mapped, and results will be issued in the near future.

An important step in the future prospecting for ores is,however, a rapid continuation of the geological mapping of the country.

Geologically, Sierra Leone has many features, which may be promising from the point of view of ore prospecting. So far apart from diamonds and gold, mainly iron ores are known, one of which - at Marampa - is mined. Furthermore, in the hills of the central part of the country large deposits of banded ironstone occur. At Hangha, chromite has been mined. Actual sulphide ores, however, are still undiscovered. The presence of minor sulphide mineralizations is known there, and they promise the possibility of finding economical sulphide ores as well, including molybdenite which occurs there even more than in traces.

In my opinion, the schist belts of the country, as well as the alkaline rocks in different parts of the country are those which should be prospected. The former are geologically similar to those of other Precambrian countries where they often associate ore deposits, as well.

## 2.Applicability of modern exploration methods

The geological reconnaissance work as well as more detailed mapping so far carried out in the country, indicate that the ordinary "old fashioned" prospecting with hammers can hardly uncover any significant ores. Therefore, aside from geological mapping, more modern exploration methods are to be used.

Keeping in mind how limited the geological survey of the country is at present, the first step in prospecting should be one which covers the whole country quickly. The airborn geophysical survey is just such a method.

It can be done in a relatively short time providing dependable topo maps or air photographs exist. Usually such a survey is done using only magnetometers. If, keeping in mind the magnetic iron ores only, the method is effective, it will indicate all ore

bodies of significant size. It does not help, however, in the finding of sulphide ores - particularly so, because pyrrhotite, which often accompanies valuable sulphide ores, is in Sierra Leone sparse, or even rare.

For this purpose airborn electromagnetic survey is of importance, and it certainly will point out all areas which are really promising for sulphide ores, even if direct discovery of such ores by the air born survey only is very unlikely. This should be anyhow the beginning of regional prospecting in such a country like Sierra Leone.

The method is expensive, but it saves very much time and also excludes large areas as unpromising, Therefore it will be finally the cheapest way to approach and even solve the actual problems. In addition it will also give much information which will facilitate and ensure the geological mapping as well, because geophysical results usually indicate important rock boundaries and tectonic features.

As mentioned above, the airborne work will indicate only the most promising areas, which need further geophysical survey on the surface. In Finland and Scandinavia, the prospecting of sulphide ores is mainly based on geophysics. Undoubtedly this must also be the case as far as the circumstances of Sierra Leone are concerned, and there especially electromagnetic methods must then be used and developed.

To my knowledge, such methods have never been used in Sierra Leone. It is true that there are certain features possibly hampering the use of these methods, such as the wide-spread lateritization. On the other hand, the oxides being the main constituents of the laterite, and the duricrust in the mountains being often comparatively thin, I would not think that this would hamper too much the use of, say, loop frame methods.

From my personal knowledge of the geology of Sierra Leone, within the mountains, there should not occur any electromagnetic anomalies other than mineralized zones and areas.

As previously mentioned, however, the best results with electromagnetic methods on the surface will be obtained only if they are used on areas found by air borne survey, because otherwise the places for such a survey are to be found haphazardly excepting a few areas already indicated by the presence of known minor sulphide mineralizations.

Furthermore, the major part of the western half of the country, which is covered by younger sediments, is probably unsuitable for such prospecting due to the thickness of the sediments.

Geochemical methods may also be of use, but from my own experience, only as subsidiary means fullfilling the interpretation of results obtained by geophysical methods.

## 3. The organization of the geophysical survey

The general program for ore prospecting in Sierra Leone, as outlined above, includes a certain amount of enlargement and re-organization of the existing survey. Despite the possible cost of such a work, it is still, in my opinion, the only way to direct prospecting, especially for sulphide ores, which may give dependable results in a reasonable time.

One of the most important points is that the geophysical prospecting should be carried out in the closest possible collaboration with geologists, and the interpretation of the results must be made strictly considering the geological data available.

For the largest program- the airborn geophysical survey - no local organization can be used, because considering the size of the country, the expenses of surveyors from abroad are still very much below those involved in the establishment of a local organization. It must be held in mind, however, that here the electromagnetic survey is of very much greater importance than solely magnetic, and therefore both are to be carried out simultaneously.

For the geophysical work on the surface, the establishment of a local organization as well as the local purchasing of instruments and equipment is urgently necessary. In actual fact, this should be done sufficiently early to enable the checking of airborn anomalies geophysically along the surface. For this purpose the purchasing of necessary equipments is less difficult, even if the loop-frame equipments have but few commercial producers. A very much more difficult problem is concerned with the recruitment of able personnel.

Because Sierra Leone itself is geologically a Precambrian country, it is of importance also that equipment purchased is suitable for such areas, and also that the people using the instruments, and in particular, those making the interpretations

of the anomalies must be tranied in Precambrian areas.

The operators as well as field assistants of such geophysical prospecting can certainly be local people trained in the beginning abroad, later on locally. The actual geophysical staff, including technicians, on the contrary, can not be obtained from Sierra Leone, but for a long time imported well trained officers must probably be used. In the writer's opinion, it is of very great importance, that, at least in the beginning, there should be in charge of superficial geophysical prospecting, a man who is not only qualified geophysicist, but also sufficiently acquainted with Precambrian geology and trained in the interpretation of geophysical anomalies with particular reference to Precambrian circumstances. This is important in order to avoid unnecessary detailed work. In addition, a technician familiar with such instruments and capable of making simple reparations is needed, because his presence on the staff can save much time and avoids sending the instruments abroad for simple reparations. His training also must take place abroad.

Thus the further development of activities for prospecting for ores in Sierra Leone needs a regional airborn geophysical survey carried out by foreign organizations. The anomalies obtained must be investigated using geophysical and geological surveys on the surface and by a local organization which should be established sufficiently early using mainly imported professional staff.

554 E - Oct. 1962 - 1,600

E/CONF.39/A/68
3 Oct.1962
ORIGINAL : FRANCAIS

CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A.4.3.1

France

# PRODUCTION D'ENERGIE AU MOYEN DE GENERATEURS DE GAZ A PISTONS LIBRES

Par P. CHAMBADAL,
Chef du Service des Recherches Thermiques,
Direction des Etudes et Recherches,
Electricité de France

et M. GARLET,
Chef de la Division Thermique,
Inspection Général
pour la Coopération Hors Métropole,
Electricité de France

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

## NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

# PRODUCTION D'ENERGIE AU MOYEN DE GENERATEURS DE GAZ A PISTONS LIBRES

par

P. CHAMBADAL, Chef du Service des Recherches Thermiques, Direction des Etudes et Recherches, Electricité de France

et M. GARLET, Chef de la Division Thermique, Inspection Générale pour la Coopération Hors Métropole, Electricité de France.

## 1. - Principe des générateurs à pistons libres

Parmi les moyens de production d'énergie mécanique ou électrique, les turbines à gaz alimentées par des générateurs pistons libres occupent une place de plus en plus importante. Certains avantages des installations de ce genre sont particulièrement appréciables pour les régions peu développées, ce qui explique qu'un grand nombre de telles installations soient dès à présent en service dans ces régions.

Le générateur à pistons libres joue, à l'égard de la turbine à gaz, un rôle analogue à celui qu'une chaudière joue à l'égard d'une turbine à vapeur : il lui fournit le fluide à pression et température élevées dont la détente dans la turbine développe la puissance mécanique désirée. La différence essentielle entre une telle turbine à gaz et une turbine à gaz du type classique consiste donc dans le fait que cette dernière entraîne elle-même le compresseur produisant l'élévation de pression nécessaire pour permettre la détente du fluide, tandis que la première ne prend aucune part à cette compression.

La figure 1 représente la coupe schématique du générateur de gaz de construction S.I.G.M.A. L'appareil est constitué par un cylindre à axe horizontal A dans lequel se trouvent deux équipages mobiles identiques et symétriques dont chacun comporte deux pistons de diamètre différent. Le combustible est injecté par l'injecteur 7 lorsque les deux équipages mobiles se trouvent au voisinage du point mort intérieur ; il s'enflamme sous l'effet de l'échauffement subi par l'air au cours de sa compression préalable : la machine fonctionne donc comme un moteur Diesel à deux temps. La pression entre les deux pistons i augmente rapidement, et les équipages mobiles sont projetés vers l'extérieur. Pendant ce

déplacement des équipages mobiles, il se produit, dans les capacités 4, une dépression, ce qui provoque l'ouverture des clapets d'aspiration 5 ; en même temps, l'air se trouvant dans les capacités 3 (ou matelas) est comprimé, et c'est la détente ultérieure de cet air qui repousse les équipages mobiles vers le centre. Les clapets 5 se ferment, et lorsque la pression dans les capacités 4 a atteint une certaine valeur, ce sont les clapets de refoulement 6 qui s'ouvrent ; l'air comprimé pénètre alors, à travers les lumières de balayage, dans la chambre de combustion et chasse les produits de combustion qui pénètrent dans un réservoir-tampon B. Un certain débit d'air pur vient se mélanger avec ces gaz de combustion, et c'est ce mélange qui se détend finalement dans la turbine C. Sous l'effet du déplacement des pistons vers le centre, les lumières de balayage (à gauche, dans la figure 1) et celles d'échappement (à droite) se ferment, et il reste entre les deux pistons 1 une certaine masse d'air pur dont la compression produit l'échauffement nécessaire à l'allumage de la nouvelle charge de combustible injectée dans le cylindre moteur 2.

## 2. - Intérêt de l'emploi des générateurs

L'emploi des générateurs de gaz à pistons libres présente plusieurs avantages qui sont énumérés ci-dessous.

a) La compression de l'air ayant lieu dans le générateur, la turbine n'a pas à entraîner un compresseur ; par conséquent, la turbine ne doit produire que la puissance utile qui lui est demandée, et non une puissance trois fois plus élevée, comme c'est le cas pour les turbines à gaz ordinaires.

b) La température à l'entrée de la turbine n'est que de l'ordre de 450°C (au lieu de 700 à 800°C pour une turbine à gaz ordinaire), ce qui permet d'utiliser pour la construction des métaux d'un prix modéré.

c) Malgré cette faible valeur de la température d'admission, le rendement global de l'installation est élevé (il est d'environ 35 %) car ce rendement est déterminé par la température atteinte dans la chambre de combustion du générateur, qui est supérieure à 1 500°C.

d) Ce rendement élevé peut être obtenu même dans des installations de faible puissance. En effet, le générateur S.I.G.M.A. est construit d'après un seul modèle fournissant une puissance unitaire de 750 kW, et c'est en alimentant la turbine par plusieurs générateurs fonctionnant en parallèle qu'on obtient des puissances plus élevées. D'autre part, les conditions de fonctionnement de la turbine permettent d'assurer à celle-ci un rendement élevé même pour une puissance de l'ordre de 750 kW ; cette double circonstance conduit, pour les installations de ce type, à des rendements qui ne varient que dans une faible mesure avec la puissance nominale.

e) L'expérience a montré que les générateurs à pistons libres peuvent fonctionner avec des fuels lourds, sans que ceux-ci doivent être soumis à un traitement autre qu'un réchauffage et une centrifugation. A l'avantage d'une faible consommation spécifique vient donc s'ajouter celui d'un bas prix du combustible ; les dépenses de combustible par kilowatt-heure sont donc peu élevées, ce qui rend possible l'emploi des générateurs pour la production d'énergie électrique de base.

f) Le démarrage des générateurs, qui est effectué à l'aide d'air comprimé, est une opération très rapide, ce qui rend ces machines

aptes à assurer aussi la fourniture d'énergie de pointe ou de secours.

g) Enfin, les générateurs alimentant en parallèle la même turbine sont mécaniquement indépendants les uns des autres ; il en résulte que l'arrêt d'un générateur ne provoque qu'une réduction de puissance, et non un arrêt complet de l'installation.

## 3. - Construction d'un générateur

La figure 2 montre la coupe longitudinale d'un générateur S.I.G.M.A. GS-34. Les diamètres des pistons composant chacun des deux équipages mobiles sont de 34 et de 90 cm. Les pistons de 34 cm (pistons moteurs) se déplacent dans un cylindre moteur 4 comprenant deux chemises en fonte et un anneau central en acier ; ces chemises sont munies de lumières (de balayage et d'échappement) dont l'ouverture et la fermeture sont produites directement par les déplacements des pistons. De même, les pistons de 90 cm se déplacent dans des cylindres compresseurs 2 qui sont munis de clapets d'aspiration automatiques 6 ; ces cylindres sont fermés, du côté intérieur, par une plaque portant les clapets automatiques de refoulement 7, et du côté extérieur, par une culasse 3. L'ensemble des cylindres est suporté par un carter de construction soudée 1, carter qui joue aussi le rôle d'un réservoir d'air de balayage.

Afin d'assurer la symétrie parfaite des déplacements des équipages mobiles, on relie ceux-ci par un embiellage de synchronisation qui doit simplement compenser les inégalités de frottement accidentelles et qui, par conséquent, peut être très léger. Les pistons moteurs sont refroidis par une circulation d'huile 9 et 10 ; d'autres organes sont refroidis par une circulation d'eau. La figure montre aussi que les pistons compresseurs sont reliés entre eux par un tube 8 qui assure la communication entre les matelas. Le démarrage de la machine est obtenu en plaçant les deux équipages mobiles près du point mort extérieur et en envoyant dans les matelas de l'air comprimé fourni par un réservoir.

## 4. - Structure d'une unité de production équipée de générateurs à pistons libres

Une unité de production équipée de générateurs à pistons libres comprend essentiellement :

- un ensemble de générateurs produisant des gaz chauds sous pression et débitant en parallèle sur un collecteur commun de gaz,

- une turbine de détente alimentée par ce collecteur et entraînant un alternateur.

Lorsqu'elle constitue une tranche d'une centrale, cette unité est généralement complétée par un transformateur-élévateur de puissance qui lui est propre.

L'aspiration de chaque générateur est munie d'un filtre et d'un dispositif antibruit. Ce dernier, rendu nécessaire par l'émission d'ondes acoustiques de basse fréquence (7 à 10 Hz) accompagnant les battements des pistons des générateurs et qui pourraient gêner le voisinage, est constitué par une capacité ou plusieurs capacités en série formant résonateurs et reliées par des venturis. On met à profit

l'existence de ce dispositif pour suralimenter les générateurs par effet acoustique (tuning).

Le trajet des gaz chauds, depuis l'entrée dans le collecteur jusqu'au rejet à l'atmosphère par une cheminée généralement métallique, se fait à pleine ouverture sans intervention d'aucune soupape de réglage. C'est en effet le cran de combustible de chaque générateur que commande directement le régulateur de la turbine (ou le variateur), au moyen d'un circuit à huile modulée commun à tous les générateurs.

Toutefois, les générateurs ne peuvent fonctionner de façon stable en dessous d'un certain débit unitaire de gaz. Aussi, aux basses charges, le circuit de régulation cesse-t-il d'agir sur le cran de combustible pour provoquer l'ouverture progressive d'une soupape de décharge placée à l'échappement de chaque générateur et aboutissant à une cheminée individuelle munie d'un silencieux.

Les mêmes soupapes de décharge contribuent à limiter l'emballement de la turbine en cas de déclenchement électrique.

L'alimentation des générateurs en fuel résiduel (genre fuel lourd n° 2 ou bunker C), qui est le combustible de marche normale dès que le facteur d'utilisation de l'unité de production en cause devient notable, se fait généralement à partir d'une cuve-relais de quelques mètres cubes. Le fuel résiduel, préalablement réchauffé et épuré par centrifugation, contenu dans la cuve-relais, y est aspiré par une pompe volumétrique pour être porté à la température assurant une bonne pulvérisation dans les cylindres moteurs, et distribué par une rampe aux différents générateurs.

Le circuit d'alimentation en fuel résiduel est doublé par un circuit distinct d'alimentation en combustible distillé (genre gas-oil, diesel-oil ou fuel domestique) à partir d'une autre cuve-relais le plus souvent commune à plusieurs unités. Le combustible distillé doit en effet être utilisé au démarrage ainsi qu'avant l'arrêt de l'unité.

Le refroidissement des générateurs est assuré par :

- un circuit fermé d'eau douce intéressant les cylindres moteurs et les plaques porte-clapets,

- un circuit d'huile intéressant principalement les pistons.

L'eau et l'huile de ces deux circuits sont elles-mêmes refroidies dans des échangeurs en relation avec un circuit primaire ouvert d'eau brute, en place duquel des ressources naturelles limitées peuvent d'ailleurs imposer un circuit fermé avec aéroréfrigérants.

Le turboalternateur est pourvu des mêmes accessoires et auxiliaires de graissage et refroidissement qu'une unité thermique classique :

- circuits d'huile combinés basse pression (graissage et refroidissement) et haute pression (sécurité, commande et régulation) actionnés par une pompe mécanique attelée au rotor de la machine, elle-même supléée par des pompes électriques en secours ainsi que lors des démarrages, arrêts et virages, et refroidis par un échangeur en relation avec le circuit primaire mentionné ci-dessus,

- l'alternateur étant généralement fermé, circuit d'eau de refroidissement de l'air de l'alternateur formé par une dérivation du même circuit primaire.

Le débit nécessaire d'eau brute de refroidissement en circuit ouvert est au total de l'ordre de 300 m3/h pour une unité de 6 MW, donc intermédiaire entre ce qu'il faudrait pour la même unité à turbine à gaz classique (50 à 100 m3/h) et à vapeur à condensation (1 500 à 2 000 m3/h).

## 5. - Considérations intervenant dans la conception générale d'une centrale

Les considérations qui suivent s'inspirent principalement, dans le sens souhaité à la présente Conférence, de résultats d'études d'équipement faites récemment à Electricité de France pour le compte de diverses Sociétés de production et distribution d'énergie électrique d'Outre-mer. Il importe de préciser qu'il s'est agi de façon générale d'unités de quelques MW dans des pays tropicaux brûlant uniquement des combustibles liquides importés, ensemble de circonstances qui ouvrent assez largement la compétition technique et économique entre les 4 sortes d'équipements thermiques possibles : diesel, vapeur, turbine à gaz à compresseur rotatif, turbine à gaz alimentée par générateurs à pistons libres, et que l'on devra garder présentes à l'esprit pour donner leur pleine valeur aux considérations qui suivent, excluant toutes hypothèses particulières pouvant rendre le choix évident telle que : au profit de la vapeur, utilisation de charbon comme combustible, puissance unitaire élevée - au profit du diesel, faible puissance unitaire - au profit de la turbine à gaz à compresseur rotatif, absence d'eau ou utilisation de gaz naturel à très bas prix;

La valeur tant technique qu'économique de chacune des 4 solutions ainsi envisagées doit évidemment être appréciée selon le service demandé à la centrale projetée. Or l'on peut, au moins théoriquement et de façon très schématique, assimiler ce dernier à l'un des deux ordres suivants :

1) service de secours, d'appoint ou de pointe, impliquant surtout : un coût modique de premier établissement, un démarrage sûr et rapide, des soins pratiquement nuls en dehors des périodes de fonctionnement,

2) service de base, où l'utilisation du matériel est à la fois plus poussée et mieux prévisible, et dans le cas duquel l'on doit au contraire s'attacher de façon essentielle aux dépenses de combustible et à la disponibilité.

Sans doute, la distinction précédente est-elle significative dans un pays industrialisé où un nombre important de centrales alimentent un réseau interconnecté et dont le développement énergétique se poursuit de façon mesurée. Mais elle peut devenir très artificielle dans un pays peu développé, où l'on a souvent affaire à des réseaux séparés alimentés chacun par une ou quelques centrales et dont la demande s'accroit de façon rapide et assez irrégulière. Or il apparaît que la formule pistons libres offre à un haut degré le caractère d'élasticité technique et économique que ces conditions feront particulièrement rechercher : fournissant la meilleure solution dans un domaine d'utilisation déjà étendu, elle correspondra encore au-delà à une opération très acceptable.

Comparé à l'équipement vapeur, volontiers retenu pour un service intensif en raison de son économie de marche et de son endurance, souvent aussi de l'habitude qu'en ont les exploitants, il offre un rendement thermique plus élevé tout en acceptant un combustible aussi ordinaire moyennant sa centrifugation préalable, et une disponibilité aussi bonne, meilleure dans le cas d'une centrale à une seule unité.

Comparé à l'équipement turbine à gaz classique à cycle ouvert et combustible distillé -solution type pour une utilisation réduite- il peut être démarré aussi rapidement en cas de besoin, un détimbrage moindre en atmosphère tropicale réduit à peu de choses son supplément d'investissements. Un dépassement de l'utilisation prévue n'a pas les mêmes effets sur les dépenses d'exploitation, grâce à un rendement nettement meilleur, surtout à faible charge, et à une possible conversion ultérieure à l'emploi d'un combustible bon marché.

Comparé à un équipement diesel, son rendement n'est pas très inférieur compte tenu des consommations respectives d'huile de graissage. L'entretien est plus facile et, au moins dans le cas d'une unité isolée, la disponibilité mieux assurée. Le diesel semi-rapide ne couvre que le début de la gamme de puissances, son fonctionnement au fuel lourd ne semble pas acquis avec un entretien acceptable. Le diesel lent type marine est plus cher d'établissement.

Le bloc usine d'une centrale à pistons libres n'est pas sans analogie de structure avec celui d'une centrale à vapeur, devant donner place d'une part à des turbo-alternateurs comme dans une salle des machines classique, d'autre part à des générateurs comme dans une chaufferie. Mais l'analogie reste assez superficielle. En effet, si l'alternateur (horizontal à 3 000 tr/mn) est le même, la turbine offre le maximum de simplicité et le minimum d'encombrement d'une turbine à gaz de détente, dépourvue de condenseur et de poste d'eau (aussi bien que de compresseur et de chambre de combustion). D'un autre côté, par opposition à une chaufferie nécessairement développée en hauteur, les générateurs se placent naturellement au niveau d'un plancher général de service et forment un ensemble moins complexe.

Ces circonstances, jointes à l'indépendance des générateurs et aux libertés de tracé du collecteur les reliant entre eux et à la turbine, confèrent à la centrale à pistons libres une souplesse de structure facilitant son adaptation aux conditions particulières rencontrées. Relativement courts, les turbo-alternateurs se prêtent à une disposition en alignement longitudinal dans un hall dès lors plus étroit d'où économies dans le pont roulant et le génie civil. Par ailleurs, les générateurs ne comportent aucune pièce lourde, demandent peu de hauteur libre et des moyens de manutention réduits (monorails). Au total les dépenses d'infrastructure et bâtiment d'une centrale à pistons libres sont sensiblement inférieurs à ceux d'une centrale vapeur ou diesel lent de même puissance, et restent assez comparables à ceux d'une centrale à turbine à gaz, du moins tant que l'on exclut la possibilité d'une installation out-door : la surface bâtie est plus étendue, mais les portées et hauteurs plus faibles pour une part.

## 6. - Exemples de réalisations

Nous nous intéresserons presque exclusivement aux unités constituées au moyen de générateurs simples GS 34 timbrés à 1 250 ch, qui équipent de nombreuses centrales en exploitation dans le monde. En effet leur épreuve industrielle s'en trouve désormais suffisante pour que, recherchant en vue d'un nouvel équipement en pays peu développé la meilleure parmi plusieurs solutions possibles, l'on n'hésite pas à inclure dans ces dernières la solution pistons libres à égalité de chances à priori avec ses compétitrices habituelles : vapeur, diesel, turbine à gaz.

### 6.1 - Unités de 6 MW

La première réalisation a été celle de Cherbourg-Equeurdreville (1 unité) en France, qui a démarré en 1956 et a fortement contribué à la mise au point industrielle des générateurs GS 34.

Actuellement, 2 unités de 6 MW viennent d'être installées à Abidjan en Côte-d'Ivoire, en première étape de la nouvelle centrale thermique.

Chaque unité a été comprise comme une tranche distincte, mais, pouvant être appelée à une marche poussée, a été équipée de 9 générateurs GS 34 au lieu des 8 suffisant à assurer de façon continue la puissance nominale de 6 MW aux bornes de l'alternateur. Cela permet à un moment quelconque d'avoir un générateur en entretien et d'assimiler la disponibilité de chaque unité à celle de son ensemble turboalternateur-collecteur de gaz.

Générateurs et turboalternateurs ont été installés dans des bâtiments distincts quoique bien entendu juxtaposés en un même bloc usine, chacun de ces bâtiments s'adaptant mieux séparément à deux sortes de matériel qui ont des servitudes tout de même assez différentes, une raison supplémentaire résidant dans l'ambiance sonore plus élevée des générateurs. Le bloc usine est complété par un bâtiment des services généraux contigu aux 2 bâtiments précédents et où prennent place principalement le poste de réchauffage et épuration du combustible, la salle des tableaux de distribution, la salle de conduite.

### 6.2 - Unités de 1,5 MW

Ces unités sont équipées de 2 générateurs alimentant un turbo réducteur. Citons la centrale E.D.F. d'Ajaccio, en Corse, qui comporte 3 de ces unités.

Retenons de divers schémas de centrales à deux unités, la souplesse de l'association générateurs-turbines, mise à profit pour retrouver malgré le petit nombre de générateurs une sécurité de marche analogue à celle de l'unité de 6 MW : cinquième générateur en supplément pouvant alimenter l'une ou l'autre turbine, ou collecteur de gaz entièrement commun aux 2 unités.

### 6.3 - Unités de grande puissance

A l'autre extrémité de l'échelle des puissances, nous ne saurions omettre la centrale E.D.F. actuellement en construction en France, à Chartres. Centrale de développement d'une technique plus avancée, elle est équipée de 12 générateurs jumelés GS 2 34 alimentant

un turboalternateur dont la puissance nominale aux bornes doit atteindre d'abord 20 MW pour être poussée ensuite à 26 MW. La technique pistons libres est donc appelée à concurrencer la technique vapeur dans un domaine de puissances unitaires interdit au diesel et intéressant particulièrement les pays peu développés.

7. - Production combinée de chaleur et d'énergie électrique au moyen de générateurs à pistons libres

La production simultanée d énergie électrique et de chaleur est habituellement assurée par une turbine à vapeur, soit du type à contre-pression, soit du type à prélèvement et condensation. Dans le premier cas, la puissance électrique fournie par le groupe varie avec le débit de vapeur nécessaire au chauffage, tandis qu'en fait, les besoins de puissance et de chaleur peuvent varier indépendamment l'un de l'autre ; dans le second, une partie de l'énergie électrique nécessaire est fournie par de la vapeur détendue jusqu'à la pression du condenseur, ce qui correspond à une consommation spécifique élevée, c'est-à-dire à un rendement médiocre.

On peut obtenir à la fois un rendement plus élevé et une plus grande souplesse de fonctionnement en combinant la chaudière à vapeur avec un moteur à combustion interne, par exemple, avec une turbine à gaz alimentée par des générateurs à pistons libres. Lorsqu'une telle turbine à gaz n'est pas associée à une chaudière les pertes par chaleur sensible des gaz à l'échappement représentent environ 41 % de la chaleur fournie par la combustion ; la combinaison de cette turbine avec une chaudière permet d'abaisser ces pertes à 7 % environ, ce qui correspond évidemment à un accroissement notable du rendement global.

Une telle combinaison peut être réalisée de plusieurs manières différentes. Ainsi, la chaudière, placée à l'aval de la turbine à gaz, peut être du type "à récupération", la vapeur étant produite aux dépens de la chaleur sensible des gaz sortant de la turbine. Il est également possible de munir la chaudière d'un foyer, en utilisant pour la combustion l'oxygène restant dans les gaz passant de la turbine[X]. De plus, la vapeur produite dans la chaudière peut être détendue dans une turbine à contre-pression, avant d'être envoyée dans les appareils de chauffage. L'étude du problème montre que, dans une installation combinée, on a intérêt à augmenter la puissance électrique produite pour un débit donné de vapeur de chauffage, donc aussi pour un débit donné d'air aspiré ; or, les générateurs à pistons libres permettent de remplir cette condition d'une manière particulièrement satisfaisante.

La production de vapeur de chauffage n'est pas le seul moyen de récupération de la chaleur disponible dans les gaz d'échappement de la turbine. Cette chaleur peut trouver aussi d'autres utilisations, comme, par exemple, la distillation d'eau de mer ou la production de froid par absorption. Toutes ces possibilités augmentent encore l'intérêt que présente la production d'énergie au moyen de générateurs de gaz à pistons libres.

X - dans la chaudière.

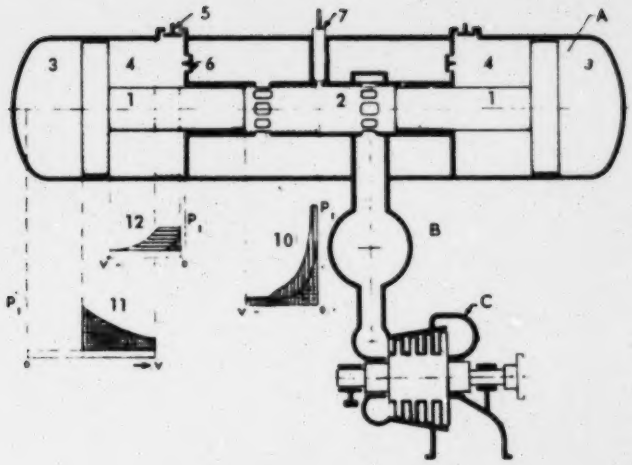


Figure 1

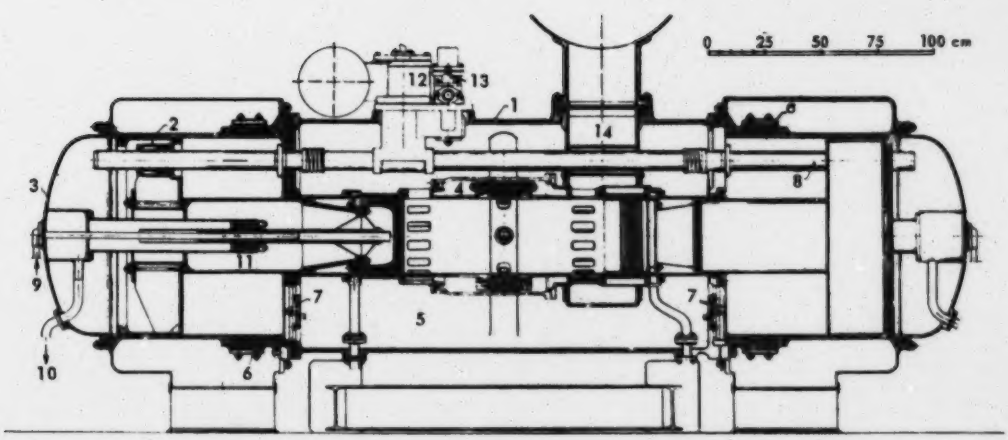


Figure 2

422 F - Oct.1962 - 1,000

E/CONF.39/A/69
4 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A. 3. 1. 2

United Kingdom

# NATURAL RESOURCES : THE ORGANISATION OF A GENERAL METEOROLOGICAL SERVICE

By D. J. BARGMAN,
Regional Representative, Tanganyika,
East African Meteorological Department

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages:

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

## NATURAL RESOURCES

### The Organisation of a General Meteorological Service

D.J. Bargman, Regional Representative, Tanganyika,
East African Meteorological Department.

1. In order that meteorological services can be of a real benefit to the less developed areas they must be, at the least, of the same standards as those in richer countries. It can be taken for granted that the indigenous peoples of the less developed areas are far from completely educated to, and capable of, running these services for which highly complex and modern techniques are indispensable. The lack of ability to pay for these services from local resources can also be taken for granted. These facts are particularly true of a modern meteorological service meeting the requirements of:

(a) aviation, both civil and military, the former being regarded as concomitant to economic development, and

(b) data collection, climatological research and advice, meteorological research, advice and forecasting in relation to the development of natural resources, particularly water resources and the requirements of hydrologists.

2. In the richer countries the meteorological services are part of a complex of interdependent highly developed facilities and the introduction of new stations, equipment or techniques only infrequently poses problems connected with the other facilities. On the other hand, in most parts of the less developed areas these facilities, particularly electrical power supplies, telecommunication services, general communications and social services including adequate housing, educational and medical services for staff and families, are absent or present in only rudimentary form. Therefore, unless general development in these progresses as fast as developments in meteorology, it falls to the meteorological service to make special arrangements for their provision. This not only adds to the cost of the service but broadens the technical responsibilities which must extend to enhance other techniques than meteorology and deepens the administrative responsibilities in large staff welfare tasks. This means that there has to be a higher degree of flexibility in the administration than is normal in the services in better endowed countries.

3. For the services mentioned in 1(a), it is necessary to have a national synoptic network of surface and upper air stations feeding into an analysis centre and associated forecast centre or centres. Additional aeronautical meteorological stations may also be necessary. Details of the network density are given in World Meteorological Organization (WMO) Technical Regulations,

Part I, Chapter 2.2. In the analysis centre and in meteorological forecast offices it is necessary to collect and process not only the information from the national network but from vast surrounding areas of continental or even near-hemispherical extent using the most modern telecommunications techniques. Data analysis and forecasting must be performed by high-grade professional staff backed by research teams capable of developing new techniques. Unless the information and staff at the high levels are available, it is impossible to satisfy the international meteorological requirements for civil aviation as laid down in WMO Technical Regulations, Part II, Meteorological Service for International Aviation, and International Civil Aviation Organization (ICAO) publications, Annex 3 to the Convention, Procedures for Air Navigation Services, Meteorology, and Regional Supplementary Procedures. Guidance on the basic scientific knowledge and the particular aeronautical meteorological knowledge are given in Guide on Qualifications and Training of Meteorological Personnel Employed in the Provision of Meteorological Services for International Air Navigation, and Parts 6 and 7 of the Instruction Manual, both volumes being produced by the International Civil Aviation Organization.

4. The policy for the services, defined in paragraph 1(a) and amplified in paragraph 3, is usually determined by a Communications, Transport or Armed Forces Ministry. More often than not full responsibility for the general meteorological service with its many facets comes under one of these Ministries.

5. For the category mentioned in 1(b) the same network and forecast facilities and staff are required supplemented by a denser network of climatological, agricultural meteorological and special stations. Again it is not necessary to expound on this network as the requirements are fully defined in Technical Regulations of WMO. There must also be a data-processing unit with high-grade professional staff interpreting the data for the various users. The WMO Guide to Climatological Practices indicates the desirable standards of this branch of meteorology and Professor J. van Mieghem's Reports on Meteorological Training on behalf of WMO as well as previously mentioned publications, outline the standards required of the staff.

6. The work, outlined in paragraphs 1(b) and 5, in most countries comes within the province of a Natural Resources Ministry and often there is a separate Ministry responsible for water resources, irrigation or hydro-electricity.

7. The major problems of organizing a satisfactory meteorological service may be summarized broadly as follows:-

(a) Divided ministerial and departmental responsibilities. It is clear that meteorology has two separate tasks; one to satisfy aviation, and one to satisfy the non-aviation interests, mainly natural resources interests. These two groups of interests are usually catered for separately by two or more Ministries. For administrative convenience, meteorology is made to come under one or other of these Ministries with the consequence that, unless special arrangements are made, one aspect of the work tends to be adequately looked after but the other tends to suffer to a greater or lesser degree.

(b) Insufficient funds to meet the cost of -

(i) an adequate synoptic network and its associated analysis centre,

(ii) an adequate network of aeronautical meteorological stations and meteorological offices,
(iii) an adequate telecommunications network and its associated telecommunications centre,
(iv) an adequate network of climatological, agricultural meteorological and special stations with its associated processing facilities,
(v) adequate instrumentation, processing and computing facilities for research,
(vi) sufficient expatriate staff, mainly at professional and senior technical level, to cover the period until local staff are trained to take over.

(c) The intense competition for the very few adequately educated indigenous people. This affects all levels of staff and tends to result in an acceptance of lower standards. There should be the strongest opposition to attempts to lower standards which should be maintained at the levels given in the guidance material referred to in paragraphs 3 and 5. An interesting point arises here in connection with indigenous staff at the professional and senior technical level. It is assumed by many Governments that the high cost of expatriate staff, 7(b)(vi), will be reduced when properly qualified indigenous staff take over; in some countries there are already different, lower, salary scales. However, there is in fact a world-wide shortage of qualified meteorologists; no nation, however well developed, has a surplus, and a person with the proper qualifications need not look to his own country for employment. Employment at world-market rates can be found by emigrating, as a WMO or as an UN Technical Aid expert in another less developed country. For example, 13 vacancies with UN salaries were advertised by WMO during the period June to August 1962. It could well turn out that the retention of even indigenous officers will imply the paying of salaries at world-market rates.

8. Possible solutions to these problems are -

(a) The formation of a National Meteorological Committee to ensure effective liaison between the user departments and interests and the responsible Ministry or Ministries. The terms of reference should allow the Committee to ensure the proper provision of finance. Members should be representative of Government and non-Government interests in both aviation and non-aviation meteorology. Particularly in the latter there should be strong representation from the agricultural, forestry, animal industry and water resources disciplines. Both practical and research aspects of the science should be allowed representation. Research, particularly in the developing countries, is vital, and a Meteorological Research Committee as an advisory sub-committee of the National Meteorological Committee ensures that research planning can be undertaken.

(b) No developing country can afford from its own funds to supply a meteorological service on a scale appropriate to modern needs. Consequently, external finance is essential and funds must be sought from both international sources and charitable foundations having an interest either generally or in a particular sector of meteorological activity.

(i) Joint support WMO/ICAO schemes should be sought to meet international commitments for aviation meteorology in their synoptic and operational aspects. Although the great benefit of rapid air communications cannot be denied, it must not be forgotten that the design, construction and operation of large fleets of modern aircraft, expensive in every aspect, rests with a very few well-developed countries. Less well-endowed countries are asked to provide the expensive facilities for the operation of these aircraft. (Should they also operate a small national airline, they have little or no choice but to buy these costly aircraft and ancilliary equipment, thus increasing local costs). In some cases there is little chance for the poorer country to recoup costs, as often only a few landings may be made for many transit flights across the national airspace between centres with greater traffic potential and where alll aircraft flying through that airspace require the same degree of meteorological protection whether or not they are landing.

(ii) Other United Nations funds, funds provided by the richer nations under aid schemes, and funds from charitable foundations, should be sought to provide or support specialized research in meteorol -ogy, hydrology and climatology.

(iii) Expatriate staff, particularly of professional or senior technical level, must be sought through United Nations OPEX schemes or National Aid schemes where much or all of the cost is borne by the outside agency. As there is usually not a career prospect for expatriates within a developing country, schemes that allow the short-term attachment of meteorologists from other countries without hindering their career in their own service are valuable in securing persons who would otherwise not serve in the developing country. The temporary loss of service by the assisting country is repaid in the long run, not only by goodwill but by the gain in special experience on the part of their own staff.

9. At this point it is appropriate to mention another method that can result in the reduction of the cost of a service normally organized on a national basis. Weather knows no political boundaries, and synoptic analysis for general meteorology and aviation route forecasting requires observations from vast areas (vide paragraph 3) and it is common for analyses to be made for areas of 20,000,000 square miles or more in extent (approximately 52,000,000 square kilometres). Synoptic climatology, forecasting research and other aspects of meteorology are also best studied on this scale. Therefore it can readily be seen that where countries are not of great area in comparison with the analysis centre, and where they are close together, the work could as easily and effectively be done once, in one regional centre, rather than be duplicated in a number of national centres. Considerable savings in money on communications and staff could ensue, and the reduced demand for professional staff would allow a more effective deployment of the small numbers available. Africa, for example, could be served by less than six regional centres rather than by some thirty national centres. These centres could

be formed by mutual agreement, as, on a smaller than regional but larger than national scale, the co-operation between Tanganyika, Uganda and Kenya supports the East African Meteorological Department, or they could be organized by WMO. The latter is preferable as it would enable international standards to be maintained and common terms of service for staff to be established. WMO and ICAO have already called for studies on this type of centre and further progress is expected after the Fourth Congress of WMO in April 1963, and the joint meeting of the WMO Commission for Aeronautical Meteorology and ICAO Meteorological Division in late 1963.

10. Another major problem is the training of indigenous staff at all levels - assistant, technical and professional. Again, WMO is very conscious of this problem. Professor van Meighem's Reports on Meteorological Training on behalf of WMO provide valuable advice and, by the time this paper is presented, WMO at its Fourth Congress in April 1963 will have no doubt progressed further in the matter. Essentially, national training should be provided for the assistant grades and extra academic training as well as technical training may be necessary. For the technical grades, regional training centres under WMO should be formed (here, association with a regional analysis centre could be possible). For the professional grades, university courses must be made available. Both for the technical and the professional grades, national meteorological services must be prepared to give academic training to promising young people to bring them up to the required entrance standard. It is not sufficient over the next decade to hope for a sufficient output from existing educational systems.

11. There are also other problems associated with the organization of a meteorological service in the less developed countries, but these are mainly matters of staff management and welfare requiring above-normal administrative techniques from the senior staff. It is not sufficient merely to have good professional men who are capable of administration. The same degree of professional knowledge is required as everywhere else in the world, but associated with this must be administration coupled with a deep knowledge of local customs and a warm human understanding. For example, junior staff who in less developed countries lack world-wide background, find difficult the stern regime of an observational science demanding day and night work and find service in an area of different dietary and religious customs, different language and different climatic regimes from their own, to be strange and thus they need special understanding.

460 E - Oct. 1962 - 1,600

E/CONF.39/A/70
4 Oct.1962
ORIGINAL : FRANCAIS

CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A.3.3.1 France

# L'INVENTAIRE RATIONNEL DES RESSOURCES HYDRAULIQUES PAR DES MOYENS MODERNES DE PROSPECTION

Par J. J. BREUSSE,
Ingénieur géophysicien
à la Compagnie générale de Géophysique

et J. TIXERONT,
Ingénieur en chef des Ponts et Chaussées,
Ingénieur-conseil de la Société Centrale
pour l'Equipement du Territoire

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

## NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: angluis, espagnol, français et russe.

4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

# L'INVENTAIRE RATIONNEL DES RESSOURCES HYDRAULIQUES PAR DES MOYENS MODERNES DE PROSPECTION

par J.J. BREUSSE, ingénieur géophysicien
à la Compagnie générale de Géophysique

et J. TIXERONT, ingénieur en chef des Ponts et Chaussées,
ingénieur-conseil de la Société centrale
pour l'Equipement du Territoire

Un inventaire rationnel des ressources hydrauliques doit commencer par définir le régime de la pluie, des cours d'eau, des sources dans les conditions naturelles Mais l'adaptation des ressources aux besoins ne peut en général se faire que par l'intermédiaire de réserves d'eau naturelles ou artificielles. Nous examinerons successivement ces deux aspects de la question :

## I - LES RESSOURCES NATURELLES

Les ressources naturelles sont accessibles à l'observation directe. Mais les stations d'observations ne peuvent être multipliées indéfiniment. Il y a des lacunes à combler, surtout dans les pays neufs. On est donc forcé par une analyse toujours plus précise des conditions naturelles, de pallier ces lacunes par des méthodes de raccordement des données dont nous allons donner quelques exemples. D'autre part, les progrès faits en matière de stations automatiques avec transmission à distance permettent maintenant de faire fonctionner des postes en des points où il serait trop coûteux de placer des observateurs. La Météorologie Nationale a équipé ainsi un vaste périmètre au Sahara.

### La pluie -

Le procédé le plus intéressant pour se rendre compte de l'étendue et de l'évolution des précipitations en l'absence d'indications pluviométriques, est l'observation au radar météorologique. Cet instrument ne permet pas encore d'évaluations numériques précises des chutes de pluie, mais permet d'explorer rapidement un vaste champ, et cette rapidité est très précieuse pour l'étude et la prévision des crues. Des applications de cette technique ont été faites en France par la Météorologie Nationale, l'Institut de Physique du Globe du Puy de Dôme et par la Société d'Etudes des précipitations (SODETEP).

Dans un autre ordre d'idées, la répartition de la pluie annuelle sur un territoire est un élément essentiel à connaître pour l'inventaire des eaux de ruissellement . Il faut donc interpoler les indications des pluviomètres. Les progrès de la phytosociologie et de la climatologie ont permis de dresser de nombreuses cartes de précipitation raisonnablement précises en tenant compte de l'exposition des versants, de leur altitude de leur couverture végétale, grâce aux travaux des professeurs GAUSSEN, EMBERGER et de leurs collaborateurs.

### Le ruissellement -

L'écoulement moyen annuel des bassins et sa variabilité interannuelles sont deux éléments importants que nous examinerons à titre d'exemple. Là également, il faut pallier les lacunes des réseaux hydrométriques. On s'est efforcé de préciser les relations du ruissellement avec la pluie, la température, les caractéristiques des sols. On a intérêt à faire intervenir la température par une fonction représentant l'évapotranspiration potentielle (Thomthwaite, Contagne, Henin, Turc, Berkaloff). Les caractéristiques des sols sont à prendre en compte. Des recherches sont en cours pour préciser leur influence sur de petits bassins, ou sur des bassins à sols plus ou moins squelettiques. Les connaissances progressent rapidement au fur et à mesure qu'elles portent sur des conditions plus variées.

On arrive à transposer les résultats des stations de jaugeages, des bassins non contrôlés non seulement pour le ruissellement moyen, mais encore pour sa variabilité. Les lois de distribution statistiques ont fait l'objet des études de Gibrat.

Elles sont en général définies par des caractéristiques simples, en rapport avec la superficie des bassins et le taux de ruissellement moyen. Les résultats obtenus dans cette voie sont constamment améliorés. L'analyse fréquentielle des besoins d'eau complète l'analyse fréquentielle des ressources (DARLOT - voir communication présentée d'autre part).

Le régime des sources ressort de méthodes d'investigation qui ne sont pas forcément différentes.

## II - LES RESERVES D'EAU

Le sol-

La réserve la plus importante est le sol. C'est une immense réserve naturelle qui conditionne non seulement l'agriculture, mais tout le cycle hydrologique. Nous avons vu son importance pour le ruissellement. Sa connaissance est indispensable pour inventorier les possibilités d'irrigations par épandage d'eaux de crues les possibilités de suralimentation des nappes, les effets et l'activité humaine sur le cycle hydrologique etc..

La variété des sols met au premier plan les problèmes de cartographie dont la solution est maintenant rendue très aisée par l'utilisation intensive de la photographie aérienne. Non seulement elle permet de tracer et préciser tous les contours, mais on voi poindre de nouvelles possibilités d'étude d'analyse sur photographie des conditions d'absorption des radiations par le sol qui conditionnent l'évaporation.

L'hydrologie du sol est devenue une des principales préoccupations des organisations qui s'occupent d'inventaire des ressources hydrauliques.

Les réserves superficielles -

Nous ne nous arrêterons pas ici au problème des réserves superficielles dont la prospection est faite systématiquement en s'appuyant sur de bonnes cartes topographiques et sur la photographie aérienne.

Les réserves souterraines -

Les méthodes de prospection des eaux souterraines maintenant classiques ont été mises au point en France par GOSSELIN. On trouvera ces méthodes exposées dans les Annales des Ponts et Chaussées (l'Inventaire des ressources hydrauliques de la Tunisie) et les ouvrages de ses collaborateurs, SCHOELLER en particulier (les eaux souterraines, MASSON - éditeur).

Un certain nombre de principes déjà exposés pour les eaux superficielles sont valables pour les eaux souterraines : hydrologie du sol, variabilité d'alimentation.

Un autre principe doit guider l'inventaire des ressources hydrauliques et son importance est de plus en plus réalisée. C'est l'interdépendance entre les eaux souterraines, les eaux superficielles et les eaux du sol. Prenons par exemple un secteur de la plaine du HAOUZ de Marrakech. L'oued Nfir apporte en moyenne en tête du secteur 140 millions de m3 dont 100 millions sont dérivés pour les irrigations et 40 millions sont évacués vers la mer. Les eaux superficielles sont partiellement régularisées par un barrage réservoir d'une capacité de 50 millions de m3. Les eaux dérivées s'infiltrent partiellement et alimentent une nappe souterraine sous jacente. La nappe souterraine est soumise à un pompage intensif portant sur environ 35 millions de m3 dont 5 environ retournent à la nappe. Cette exemple suffit à montrer que :

a/ la ressource souterraine est en fait incluse dans les 140 M de ressource superficielle.
b/ les réserves sont par contre indépendantes - elles s'ajoutent.
c/ l'utilisation optimum des eaux ne peut être fixée qu'après avoir procédé simultanément à l'inventaire de toutes les réserves et précisé les échanges entre eaux superficielles et nappes souterraines.

Parmi les méthodes et procédés modernes de prospection et d'inventaire qui caractérisent l'hydrologie actuelle, nous nous limiterons aux suivantes :

a/ nous avons vu la nécessité d'un inventaire intégré des ressources. Cette nécessité amène à systématiser au maximum le travail d'inventaire par l'établissement de cartes hydrologiques et hydrogéologiques régulières

b/ lorsqu'on connaît bien les conditions climatiques, topographiques, géologiques d'une nappe, et ses conditions d'exploitation, on peut étudier sur modèle son fonctionnement en reproduisant les conditions d'une série d'années connues, et on en déduira les conditions de fonctionnement permises par des travaux de captages et d'amélioration hydrauliques projetés. La méthode du modele électrique est surtout employée en France en raison de sa simplicité et de son faible coût(MALAVAUD).

c/ l'utilisation des isotopes radioactifs est une technique très moderne dont on attend des résultats importants dans l'étude des bilans d'eau.

d/ on connaît mieux maintenant les possibilités des méthodes de prospection géophysique proprement dite dérivées des travaux initiaux de SCHLOMBERGER.

Nous insisterons dans le chapitre suivant sur ces dernières méthodes.

## III - LES METHODES DE PROSPECTION GEOPHYSIQUES

Présentons les principales méthodes de prospection : électrique, sismique réfraction.

En prospection électrique, on sait que la résistivité d'un terrain dépend beaucoup des propriétés physiques et chimiques de l'eau d'imbibition et de sa teneur, d'où les larges variations de ce "paramètre", de 0,I à plusieurs milliers d'ohms. Elle permet de comparer, qualitativement tout au moins, les perméabilités des alluvions et formations meubles. C'est ainsi que pour une même eau d'imbibition, une alluvion sera d'autant plus perméable qu'elle sera électriquement résistante, tandis que, dans une masse compacte, une zone faillée se marquera par une bande conductrice.

Le sondage électrique mesure la résistivité apparente en fonction de la profondeur. La carte de résistivité, au contraire, la fait connaître, à profondeur constante, sur tout un périmètre. La prospection électrique se distingue par une grande facilité de mise en oeuvre. Elle est très souple, s'adapte immédiatement à des problèmes variés et conduit à des économies importantes par la suppression des forages mal placés (50 à 70 % selon des chiffres présentés à la Conférence Inter-Africaine d'Hydrologie, NAIROBI, Janvier I96I). Elle s'appuie sur une interprétation mathématique, donc scientifique, des diagrammes.

On a songé à utiliser les courants naturels de la polarisation spontanée, causés par les phénomènes d'électrofiltration et d'évaporation à la surface des terrains détritiques et de certains massifs de roches poreuses. En reconnaissance générale, la polarisation spontanée aiderait à localiser des zones de plus grand coefficient d'infiltration de l'impluvium et même à repérer des nappes peu profondes . L'expérimentation mériterait d'être poussée en pays tropicaux et semi désertiques. En revanche, ces essais pratiques de polarisation provoquée n'ont pas été encore très probants, les phénomènes étant surtout fonction de la teneur en argile.

La sismique réfraction, met en jeu les vitesses de propagation des ondes sismiques. On l'emploie surtout à reconnaître sous des alluvions, l'allure du rocher ; elle vient, au secours de la méthode électrique qui est en difficulté lorsque les résistivités des alluvions et du rocher sont trop voisines. Pour des études structurales profondes (plusieurs centaines de mètres) la sismique réfraction intervient dans des cas particuliers, par exemple étude d'un horizon calcaire aquifère. Comparée à la prospection électrique, la sismique réfraction est beaucoup moins sensible aux faciès des terrains, à leur altération et ne fournit pas d'indications de la perméabilité. Sa mise en oeuvre est plus complexe, son prix de revient est plus élevé. Elle constitue donc une méthode d'appoint,

Pour mémoire, citons la méthode magnétique, efficace sur les formations volcaniques, pour reconnaître, par exemple, des coulées de lave ou des dykes.

Examinons maintenant les différents problèmes qui sont posés couramment au géophysicien. En premier lieu viennent les études des nappes alluviales et des dunes. Il s'agit d'estimer des épaisseurs d'alluvions, de découvrir des anciens lits et sur leur tracé, localiser les zones les plus perméables, de connaître le substratum, de dicerner les formations imbibées d'eau, d'en apprécier la salinité, de localiser les limites entre nappes d'eaux douces ou salées.

Des problèmes techniques sont également posés : préciser en profondeur, l'allure d'un terrain qui, connu en affleurement, se révèlera aquifère et peut-être artésien. On étudie les failles, horst et grabens, anticlinaux et synclinaux et surtout les seuils hydrauliques. En présence de formations volcaniques on met en évidence les coulées de laves et les tufs perméables avec l'ancien réseau hydrographique.

En résumé, peu de problèmes échappent à l'investigation géophysique, hormis ceux que soulève le véritable registre karstique des eaux dans les calcaires. Mention doit être faite ici du carottage électrique. Il est devenu une aide indispensable à la prospection des formations hydrauliques par sondage et son exécution accompagne de plus en plus systématiquement les forages de prospection.

Citons quelques exemples de prospection hydrologique :

Plaine de CATANE (Italie) - cet exemple se rapporte à l'étude hydrologique générale de la plaine de Catane dont la superficie dépasse 300 km2 ; Un partie est couverte par des coulées de basalte, le reste du bassin par des alluvions : alluvions grossières et en terrasses, masquées ou non par des limons argileux. Ces formations reposent sur des argiles bleues quaternaires constituant le plannher imperméable, au-dessus du tertiaire sous jacent déjà connu sur les bordures.

De nombreuses explorations s'étant révélées stériles, il a été demandé à la méthode électrique d'éclaircir les possibilités aquifères du tertiaire sous-jacent et de certains bancs sableux intercalés dans les argiles bleues quaternaires et de préciser le tracé de l'ancien réseau hydrographique. Quelques sondages électriques ont montré qu'il existait sous le recouvrement alluvial volcanique, une formation conductrice correspondant à des épaisseurs d'argiles bleues, beaucoup plus importants qu'on ne l'imaginait. Ils ont également indiqué que les bancs sableux étaient trop minces ou trop imbibés d'eau salée. Il restait à préciser le tracé de l'ancien réseau hydrographique. Grâce à de nouveaux sondages électriques il a été construit une carte en courbes de niveau du toît des argiles bleues. Cette carte montre que le massif argileux culmine au Nord de l'étude. Il est entaillé par un puissant réseau hydrographique qui, sous les laves, collecte la majorité des eaux.

Les forages exécutés à la suite de ces conclusions, ont été couronnés de succès. Ceux qui ont été implantés sur le lit de l'ancien fleuve Simeto, ont rencontré de puissantes nappes artésiennes.

Seuil hydraulique de SBEITLA (Tunisie) - Un miocène gréseux à intercalations marneuses repose sur une série marno-calcaire du crétacé supérieur dont les bancs calcaires se comportent probablement comme des collecteurs d'une partie des nappes miocènes. Les relevés géologiques laissaient prévoir la présence d'une grande faille capable de constituer un seuil hydraulique.

Le tracé de la faille a été précisé par onze profils de résistivité. Une lentille résistante gréseuse signalée par la prospection, entre des bancs calcaires pouvait être aquifère. Un forage a effectivement rencontré 120 mètres de grés donnant une eau jaillissante. Plus bas il a touché à 360 mètres les calcaires également aquifères.

Plaine de WARNIER, région d'ORLEANSVILLE(Algérie) - Un forage profond, destiné à l'alimentation en eau, devait être placé dans les meilleures conditions à l'intérieur d'une surface de 6 km2. Sous les dépôts quaternaires se rencontrent les couches marno-sableuses du Villafranchien, des limons et des grès, puis les sables et grès de l'Astien, les marnes bleues du Plaisancien, les grès sableux et conglomérats de base du Pliocène, enfin les marnes du miocène supérieur. En profondeur, plonge le périclinal d'un anticlinal à coeur de miocène marneux affleurant.

Par sondage électrique, il a constaté qu'un horizon repère est constitué par le toît des marnes plaisanciennes et, en cas de disparition du plaisancien, par le toit des marnes miocènes. Il est donc possible de suivre le sustratum imperméable, conducteur. Une carte en courbes de niveau, déduite de l'interprétation des sondages électriques, dégage l'allure de ce substratum et indique, comme favorable, une zone où sa profondeur n'excède pas 350 m. Le forage placé en fonction des données géophysiques pénètre dans les marnes plaisanciennes à 284 m de profondeur et assure un débit artésien de 14 litres-/secondes.

Une campagne de mesures de résistivité a permis dans la plaine de Marrakech dont il a été question plus haut, de définir la position du socle schisteux constituant le substratum imperméable de la nappe aquifère de la plaine du HAOUZ.

EN CONCLUSION -

L'inventaire des ressources hydrauliques dispose maintenant d'une gamme de moyens de prospection modernes qui ont permis de développer toutes les branches de l'hydrologie :

Inventaire des ressources naturelles : pluie, eaux de ruissellement, eaux de source.

Inventaire des réserves : indispensable à l'adaptation des ressources aux besoins, compte tenu de leurs variabilités ; notamment, inventaire des eaux souterraines au sujet desquels nous avons insisté sur les méthodes géophysiques, méthodes de prospection rapides indispensables en certains cas.

Les ressources et les réserves de diverses natures se complètent mutuellement. Elles doivent être étudiées systématiquement et simultanément dans un inventaire rationnel dont la nécessité est devenue urgente dans tous les pays.

556 F - Oct. 1962 - 1,000

E/CONF.39/A/71
4 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3

Sierra Leone

# WATER RESOURCES IN SIERRA LEONE

By E.J. DAVIES, B.Sc.,
AMICE., AMIWE, MASCE, Member AWWA,
Assistant Director of Public Works

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

## NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

# WATER RESOURCES IN SIERRA LEONE

BY

E. J. DAVIES, B.Sc. AMICE. AMIWE, MASCE

MEMBER AWWA

ASSISTANT DIRECTOR OF PUBLIC WORKS.

## INTRODUCTION

Sierra Leone is essentially an agricultural country, more than 4/5ths of its population of an estimated 2½ million living in the rural areas. Hence it has few large centres of population, the largest being its capital, Freetown, whose population has been estimated variously as being between 100,000 and 200,000 people.

2. The whole Country lies in the equatorial forest region and is therefore subject to the usual extremes of heavy rainfall and long periods of drought, which are associated with areas similar to the monsoon areas of Asia and the Far East.

3. Rainfall is heaviest in the coastal belt which consists of a narrow pene-plain backed by high mountain ridges which make favourable conditions for heavy rain from moisture laden south-westerly winds from the Atlantic (Fig I). The heaviest rainfall is about 200" per annum on the coast and rainfall decreases as one proceeds inland to about 40" per annum in the extreme north-eastern corner of the Country.

4. Geologically the coastal areas consist of sedimentary deposits of the bullom series overlying igneous rocks. Over the rest of the Country the igneous rocks, in some cases metamorphosed to clays, shales and schists persist - Fig II.

5. Eight main rivers form the principal drainage system of the Country. The Great Scarcies forms the boarder with Guinea on the North-West and is the largest river in the territory. Next are the Little Scarcies, the Rokel or Seli, Gbangbaia, Taia, Sewa, Wanje and the Moa, which in its Northern reaches forms part of the Eastern frontier between Sierra Leone and Guinea - Fig III.

## APPRAISAL OF EXISTING RESOURCES, USES AND REQUIREMENTS AND ALLOCATION TO DIFFERENT USES

### Surface Water

6. Fig III shows the layout of the main drainage system and Table I gives estimated values of run off from this system. In addition to these sources, ample water exists in the rivers of the minor tributary system but these are subject to large variations in seasonal flow so that their use would in many cases involve the construction of dams for impounding water from the rainy season run-off for dry season use.

7. Due to the relatively low population density the use of the main drainage system as centralised sources of urban supply does not at the present time appear practicable.

8. The phenomenon observed in the more industrialised parts of the World that large townships develop along river banks for the usually given reasons of accessibility by water and the proximity of water for use, is not observed in Sierra Leone, for the principal reason that the physical nature of the Country is such that its rivers are

navigable only for a short distance inland from the point of entry into the sea. Therefore, the large rivers, which are the assured sources of a sufficient quantity of water for urban development, are not usable for this purpose without a great expense in aqueducts to convey the water from the rivers to the towns. Often, because of the lack of information on the quantities in the minor drainage system, a large expenditure has been undertaken to provide water from the main drainage systems in the few townships which are now developing.

9. Facilities do not at present exist for collecting and formalising the information necessary for economic use to be made of the Country's resources in surface water. In order that the best use may be made of these, it is of paramount importance that facilities be established for collecting the basic hydrological and meteorological information needed in economic design. The main deterrents to the realisation of such a recording system are the lack of funds and personnel. Preliminary estimates for such a system amount to about £100,000 - a sum about twenty times the total amount which the Government of Sierra Leone has found it possible to expend for this purpose in the past eight years.

10. The usefulness of any water resources survey carried out must be conditioned by knowledge of present populations and a reasonable forecast of population growth, by a clearly defined but flexible plan of overall development, including industrial development, and by the degree of accuracy with which the parameters which affect the stream flow are determined.

11. Since other methods of power development within Sierra Leone would depend on the importation into the Country not only of materials for power generation, but also for the continous importation of materials for the up-keep and maintenance on these units, the economy of the Country would stand to benefit by the utilisation of local material, in this case in the form of harnessed water power for power generation for industrial and urban use. Reliable information on the potential of the surface water is also of prime importance in the planning of irrigation schemes for the production of more food. For these reasons as well as for the use of water as such in supplies to urban communities, it is important that such a network of river gauges be established around the Country on its main and subsidiary drainage system in order that reliable estimates of the yield may be determined.

12. Such recording stations would have to meet requirements which are peculiar to areas similarly placed as Sierra Leone. For instance, the lack of suitably trained personnel to man and reliably observe these gauges make it necessary that they should be self-recording and integrating so that analysis only at a centralised place, manned by the few trained people available, would be necessary.

13. Detailed studies of the percolation and other physical factors can commence at a subsequent date to the actual measurement of stream flow.

14. The measurement of flows from selected streams in the subsidiary drainage system, which will constitute the main source of surface water for urban use, can be carried out simultaneously with the measurement of flows from the main drainage network.

15. The work outlined above can best be done in a hydrological section of the Public Works Department manned by two hydrologists.

Ground Water.

16. No estimate of underground water sources has been made. Percussion equipment capable of drilling 6" and 8" boreholes to depths of 800 is now on order and it is hoped, whilst installing water supplies in a few places with the help of this equipment, to collect enough information to enable a preliminary assessment of underground water resources to be made. In the context of the observation that large townships do not grow on river banks of Sierra Leone, it is important that wherever possible such ground water reserves as exist should be developed to the fullest before recourse is had to the more expensive alternative of transporting surface water from long distance.

17. Due to the largely forest nature of the Country, preliminary surveys connected with borehole location and levels are very arduous and time-consuming. It is hoped that help will be available in utilising the aerial photographs which now exist for most of the country to reduce the time and labour involved in this aspect of the work; however, before this can be done, a lot more knowledge in the geological and emological

photo-interpretation of the aerial photographs and more ground control are necessary. It is necessary that a technique be developed with a high degree of accuracy for locating possible sources of ground water from these aerial photographic studies aided by adequate ground control.

18. There is not in the Public Works Department, personnel trained in operating borehole drilling equipment and it is planned to recruit staff from overseas for this purpose in the first instance. The early stages of prospecting work for using this equipment will be carried out entirely without the help of the aerial photographs, but the result obtained from the first few boreholes, with detailed geological studies of the area co-ordinated with the aerial photographs, should give enough pointers for locating future boreholes. Such information as is available from similar studies carried out elsewhere, would be of great value to the Government of Sierra Leone.

19. The use of waters in plutonic reservoirs has not been contemplated. It is hoped that boreholes of medium reach would in these early stages be sufficient for the needs of most centres of population. In a particular area of Sierra Leone, namely in Bonthe Island, preliminary drilling has shown that water reservoirs are available within 200 ft. of the ground surface, but difficulty is contemplated that with draw-off at the rate of consumption, salt-water intrusion is likely. Some thought is being given to the problem now of providing suitable safeguards against the expected advance of the salt-water interface.

20. In areas removed from sources of surface water, shallow wells have been dug and have been in use by indigenous communities. The hazards and limitations of the shallow well are manifold.

Main Water Uses.

21. In the present state of development of the Country, the main water uses are domestic and urban, while there is little doubt that with the increasing trend towards industrialisation, there will be an increasing use of water for industrial purposes. At present less than 5% of the total water consumed over the Country is applied to those uses which are described as industrial in other countries. More than 90% of the water supply for urban and domestic purposes is obtained from surface sources by impounding where necessary the surface run-off from the main and subsidiary drainage systems of the Country.

22. It is a paradox that on the coastal plain where the greatest precipitation occurs, the greatest want for water in periods of no precipitation is felt. Historically this is due to the rapid growth of urbanisation in the Western coastal plains - at a rate exceeding any which could have been forecast when the urban water supply system for the capital, Freetown, was first installed more than 70 years ago.

23. The use of water for urban and domestic purposes will continue at a rate faster than was hitherto encountered for the per capita consumption will be at an increasing rate by a population which is itself increasing. An appraisal, therefore, of the water needs must be based on forecast of future requirements. Because of the large number of unpredictables which are associated with such a forecast, it is not considered good practice to forecast for a period exceeding fifteen years.

24. On this basis, the needs of the urban communities are as shown in Table 2. This includes a certain provision for an increased consumption for industrial purposes - Fig IV.

25. In rural communities there is a tendency for central Government to participate in the development of rural housing schemes tending to alter the consumption pattern of rural communities. Present thinking on the design of rural communities leads to a large land allocation per house, which in turn is reflected in a high per capita consumption of treated water. In a non-directed growth of rural communities the water needs would be divided into two types:-

(a) treated water for human and animal consumption and

(b) raw water for irrigation and other farm purposes.

Hence, one significant result of Government participation in rural and sub-urban housing schemes is that the cost of such schemes as reflected in the water supply costs is higher than would have been the case otherwise.

## A.1.1.2 - ORGANISATION OF METEOROLOGICAL AND HYDROLOGICAL SERVICES

26. Government maintains a Meteorological Department but not a Hydrological one. Hydrological information is collected principally by the Public Works Department, the Land Reclamation Section of the Department of Agriculture and to a small, but increasing extent, by the University College of Sierra Leone.

### Rainfall

27. Rainfall records are collected in 22 stations by the Meteorological Department and agents of this Department. In one of these 22 stations there is a recording rain gauge from which storm intensity data can be evaluated. All other sources are daily observation stations and only the total precipitation in a 24-hour period is obtained, - Fig V. The need for storm intensity observation in more than one station must be obvious in view of the fact that the relationship between the average rainfall in the wettest and driest parts of the Country is about 5 to 1.

28. As most schemes in use at present have surface water sources involving impounding, the design of spillways, which must be conditioned by storm intensities, is at present based on a conjectural co-relation of average rainfall in the area of the project with that at the station in which there is a recording rain gauge. The fact that no catastrophic results have followed this method of design is not to be interpreted as establishing the validity of the process, but is due to a conscious over-designing - a process which is uneconomical and undesireable in a country which must husband its viable resources.

### Evapo-Transpiration

29. There is little literature available on the relative percentages of precipitation which are disposed of by evaporation, transpiration, percolation and run-off. Again the proportions of these are determined by conjecture in any one scheme with a strong bias towards conservative estimation. Studies (2) carried out at Lungi Airport, near Freetown, on a surface evaporimeter and applying Penman's formula, show evaporation in inches to be as tabulated in Table 3. Transpiration studies have not been carried out within Sierra Leone to an extent which would give explicit results. The need for detailed studies in this area as an aid to the economic design of water supplies cannot be over-stressed.

### Stream Flow Studies

30. The Public Works Department carries out ad hoc studies of stream flow in connection with all water supply schemes. There is, as such, no network of stream flow observation stations over the Country, although the desirability of such a network in order to establish the potential of the available sources is recognised (Para. 6 - 13). None of the rivers forming the main drainage pattern of the Country have been studied in detail. Various estimates of seasonal flow from sources have been given, the most recent of which gives estimates of flow as one-third the precipitation. Such an approximation has led to the estimated flows shown in Table 1 (1).

31. A particular problem associated with stream flow studies arises when it is proposed to instal a new water supply scheme in a township using one of the tributaries of the main drainage system. In such cases Public Health and Political requirements demand that the scheme be installed after only one dry season observation of the flow at source. In such cases it is sometimes not practicable to assess the degree of confidence which is applicable to the reliable yield assumed and such a procedure almost always leads to very conservative and probably uneconomic design.

32. In some of the existing meteorological stations rainfall observations have continued for more than 30 years so that it is now possible for the records to be analysed and a pattern of the rainfall described. The lack of a hydrologist and the pressing demands of other work from trained staff have not made such a study possible. In this respect some help can be given with the recruitment of a trained hydrologist to be attached to the Public Works Department to help make the greatest use of the information already assembled. Such an expert would need to be in the Department for a period of approximately two years.

33. In addition to such an expert, two other trained hydrologists would be needed to organise the location of further rain gauges, in the areas where they are most likely to be needed. These rain gauges, being of the recording type, would give further information on the rainfall pattern from which interim results would be assembled. If the organisation of stream flow records mentioned earlier is undertaken at the same time, further useful information would be obtained by relating stream flow with such rainfall measurement as are made.

34. Simultaneously with stream flow and rainflow observations an effort could be made to determine local values for the variants associated with evapo- transpiration, either by applying one of the established procedures used in other areas, or by independently determining the procedure which would be applicable to this area. Information derived from such methods would provide the material which is necessary to ensure that the best use is made of the water available and funds allocated for its development.


1. WOODACRE B. - GOVERNMENT METEOROLOGIST, PRIVATE COMMUNICATION SEPTEMBER, 1961.

2. VORM W. LAHMEYER & CO. - "HYDRO-ELECTRIC SCHEMES IN SIERRA LEONE" - 1961.

# SIERRA LEONE

## MAIN DRAINAGE.
## CHART OF RUNOFFS.

Table 1.

| NAME OF RIVER. | AT. | Annual mean. | | | Max. monthly mean. | Floodwater. |
|---|---|---|---|---|---|---|
| | | Average year cuft/s | Net year cuft/s | Dry year. cuft/s | cuft/s | cuft/s. |
| Great Scarcies | Kychom | Not available | Not available | Not available | Not available | Not available. |
| Little Scarcies | Mange. | 17,597 | 21,413 | 13,993 | 57,243 | 173,145. |
| Rokel | Rokel | 6,926 | 8,375 | 5,795 | 24,205 | 74,205. |
| Gbangbaia | Moselolo | 18,400 | 22,200 | 15,400 | 64,500 | 197,500. |
| Jong | Matru | 2,260 | 2,740 | 1,895 | 7,900 | 24,200 |
| Sewa | Sumbuya | 4,200 | 5,100 | 3,500 | 1,470 | 4,520. |
| Waanje | Pujehun | 26,600 | 32,200 | 22,900 | 92,500 | 283,000 |
| Moa | Sulima. | 3,600 | 4,400 | 3,020 | 12,400 | 38,300. |
| Mano | Mano Salija. | 55,000 | 67,700 | 46,000 | 194,000 | 595,000 |
| | | | | | | |
| | | | | | | |
| | | | | | | |

# SIERRA LEONE

## PROJECTED URBAN WATER SUPPLIES

TABLE 2.

| TOWNSHIP | PRESENT | | | FUTURE 1975 | | |
|---|---|---|---|---|---|---|
| | POPULATION | PER CAPITA DEMAND | TOTAL DAILY DEMAND | POPULATION | PER CAPITA DEMAND | TOTAL DAILY DEMAND. |
| SEGBWEMA | 6000 | 15 | 90.000 | 20,000 | 20 | 400,000 |
| KABALA | 6000 | " | 90.000 | 20 000 | " | 400 000 |
| JAIAMA NIMI KORO | 6 000 | " | 90,000 | 12 000 | " | 240 000 |
| YENGEMA | 2,000 | " | 30,000 | 8 000 | " | 160 000 |
| MAMBOLO | 4 000 | " | 60,000 | 10 000 | " | 200 000 |
| MATTRU | 6000 | " | 90.000 | 15 000 | " | 300 000 |
| SUMBUYA | 5000 | " | 75.000 | 10.000 | " | 200.000 |
| KASSIRI-KYCHOM | 4 000 | " | 60.000 | 8.000 | " | 160.000 |
| BLAMA | 5000 | " | 75.000 | 10 000 | " | 200.000 |
| MAKALI | 2000 | " | 30 000 | 5.000 | " | 100.000 |
| POTORU | 2000 | " | 30 000 | 6,000 | " | 120.000 |
| SONGO | 2000 | " | 30 000 | 4.000 | " | 80 000 |
| MATEBOI | 2000 | " | 30 000 | 4,000 | " | 80 000 |
| BATKANU | 4000 | " | 60 000 | 8,000 | " | 160.000 |
| MANO | 5000 | " | 75.000 | 8,000 | " | 160.000 |
| ROTIFUNK | 6000 | " | 90,000 | 10,000 | " | 200 000 |
| GBANGBATOK | 2000 | " | 30,000 | 8.000 | " | 160 000 |
| JIMMI GBAGBO | 2000 | " | 30,000 | 4 000 | " | 80 000 |
| KAMAKWIE | 6000 | " | 90.000 | 15 000 | " | 300.000 |
| BONTHE | 6000 | " | 90,000 | 8000 | " | 160.000 |
| TIHUN | 2000 | " | 30,000 | 5000 | " | 100,000 |
| | | | | | | |



A/72

## SIERRA LEONE EVAPORATION LUNGI 1950-1959
## TABLE 3

| MONTH \ YEAR | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | MEAN MONTHLY EVAPORATION INCHES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JANUARY | 5·9 | 5·9 | 4·6 | 4·3 | 5·7 | 6·1 | 5·7 | 5·6 | 5·7 | 5·0 | 5·5 |
| FEBRUARY | 5·8 | 5·8 | 6·6 | 6·0 | 5·8 | 6·4 | 5·8 | 6·0 | 5·7 | 5·7 | 6·0 |
| MARCH | 6·3 | 7·1 | 7·0 | 7·7 | 7·0 | 6·7 | 7·1 | 6·8 | 7·0 | 6·5 | 6·9 |
| APRIL | 6·9 | 7·0 | 7·0 | 7·1 | 6·1 | 6·0 | 6·9 | 6·9 | 6·1 | 7·1 | 6·7 |
| MAY | 5·6 | 5·4 | 6·3 | 6·3 | 6·0 | 6·0 | 6·3 | 6·1 | 5·3 | 5·4 | 5·9 |
| JUNE | 5·4 | 5·1 | 5·3 | 4·4 | 4·4 | 4·7 | 4·8 | 5·0 | 4·6 | 5·0 | 4·9 |
| JULY | 3·7 | 4·3 | 3·9 | 4·2 | 3·7 | 4·0 | 3·5 | 3·7 | 3·7 | 3·7 | 3·8 |
| AUGUST | 3·5 | 3·5 | 3·4 | 3·9 | 3·3 | 3·8 | 3·7 | 4·3 | 3·5 | 3·9 | 3·7 |
| SEPTEMBER | 4·1 | 4·6 | 4·6 | 4·6 | 4·3 | 3·9 | 4·5 | 4·1 | 3·9 | 4·1 | 4·3 |
| OCTOBER | 5·1 | 4·6 | 5·9 | 5·0 | 5·2 | 5·0 | 5·5 | 4·8 | 5·1 | 5·3 | 5·1 |
| NOVEMBER | 4·7 | 4·8 | 4·8 | 5·2 | 4·7 | 5·5 | 5·0 | 5·0 | 4·4 | 5·0 | 4·9 |
| DECEMBER | 5·4 | 5·4 | 5·0 | 4·6 | 5·0 | 4·9 | 4·5 | 5·3 | 4·8 | 5·3 | 5·0 |
| TOTAL | 62·4 | 63·5 | 64·4 | 63·6 | 61·2 | 63·0 | 63·3 | 63·6 | 58·8 | 62·0 | MEAN YEARLY 62·7 |

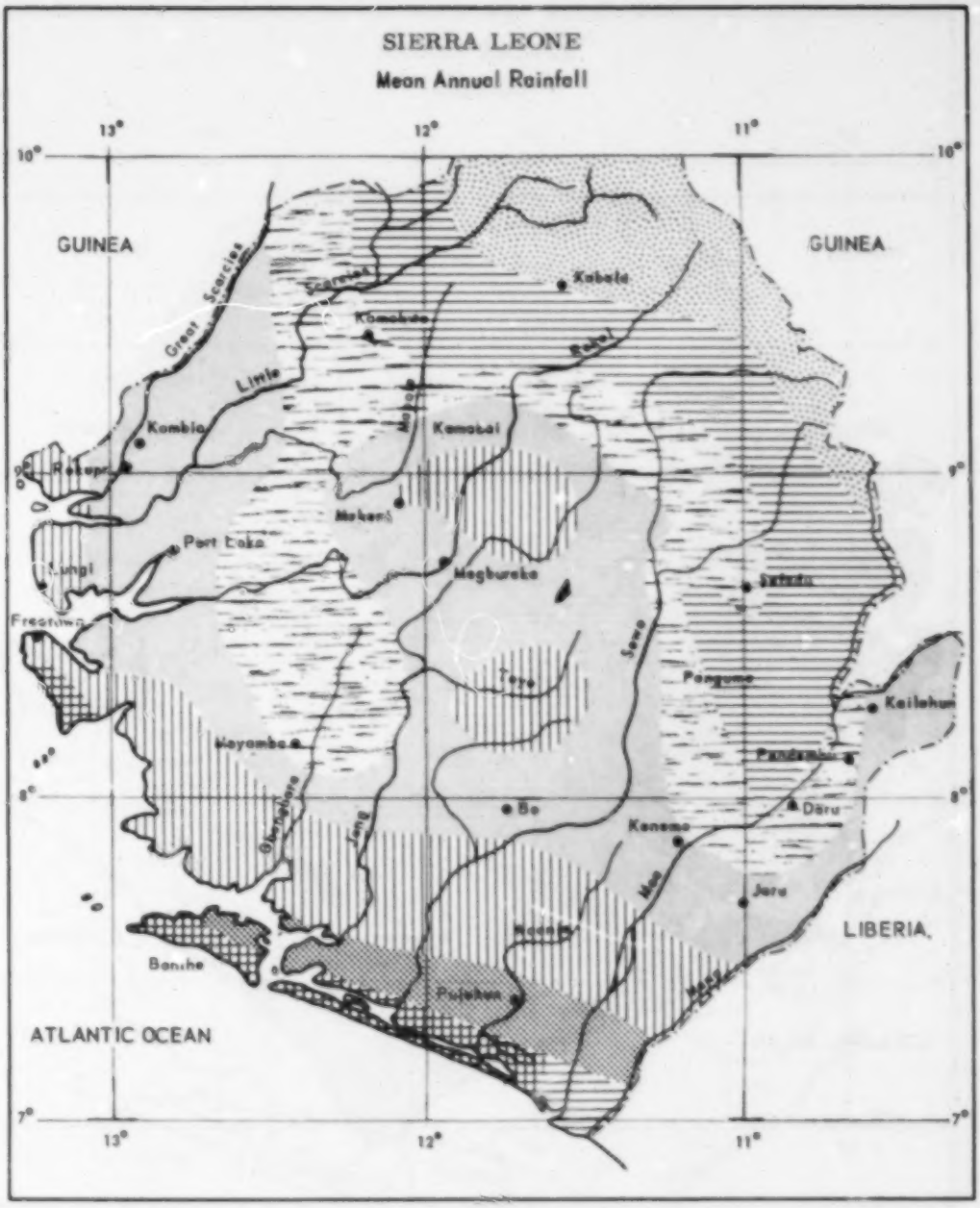


Fig. 1

| | |
|---|---|
| 160 | 100-110 |
| 140-160 | 90-100 |
| 120-140 | 80-90 |
| 110-120 | |

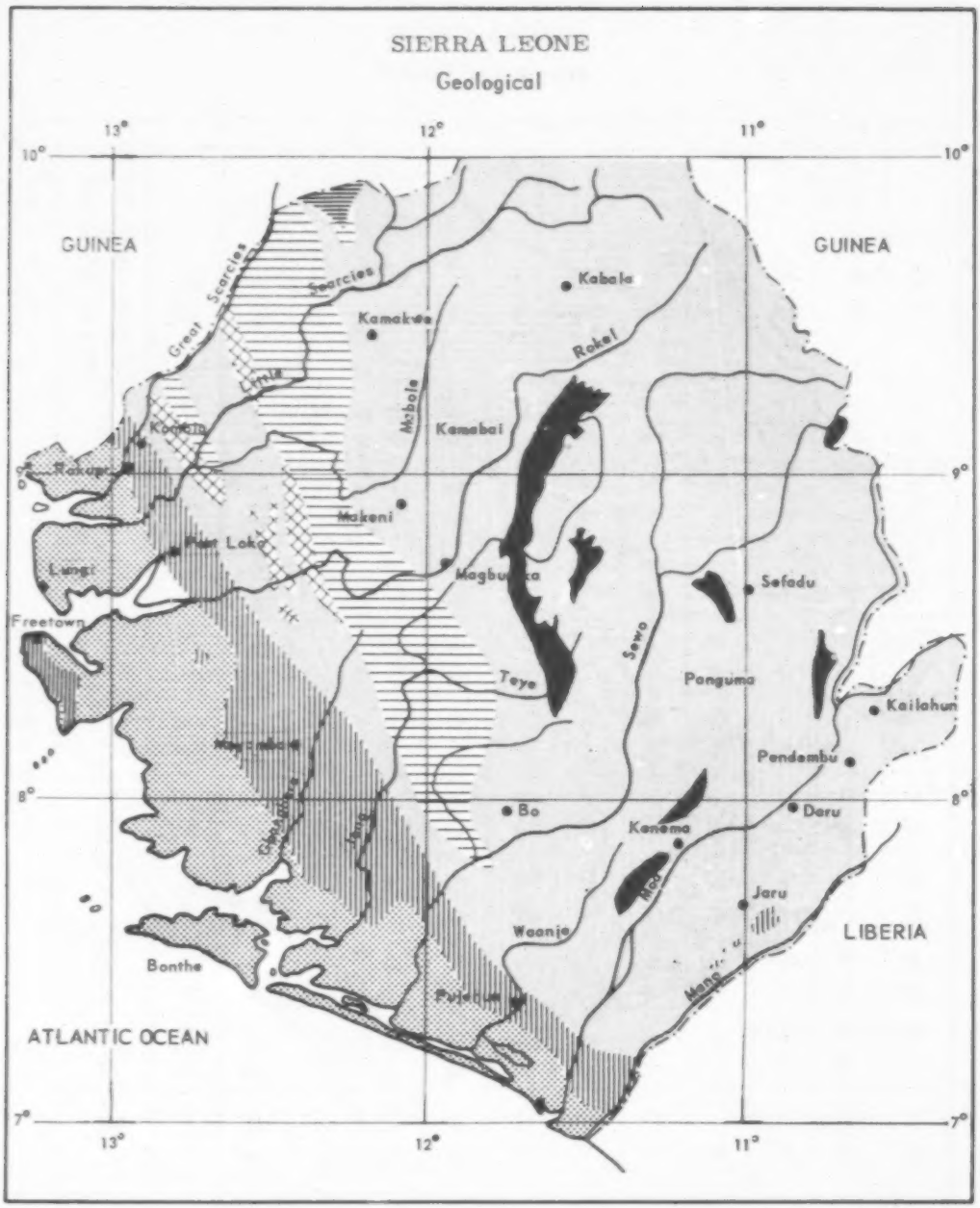
SIERRA LEONE
Geological
13°
12°
11°
10°
9°
8°
7°
GUINEA
GUINEA
LIBERIA
ATLANTIC OCEAN
Great Scarcies
Scarcies
Little
Mabole
Rokel
Kabala
Kamakwie
Kamabai
Koinadugu
Rokupr
Makeni
Port Loko
Lungi
Freetown
Magburaka
Sefadu
Sewa
Taye
Panguma
Kailahun
Pendembu
Bo
Kenema
Daru
Jaru
Waanje
Bonthe
Pujehun
Mano
Bullom Series
Saionya Scarp Series
Rokel River Series
Marampa Schists
Kambui Schists
Kasila Series
Norite and Gabbro
Granite

Fig. 2

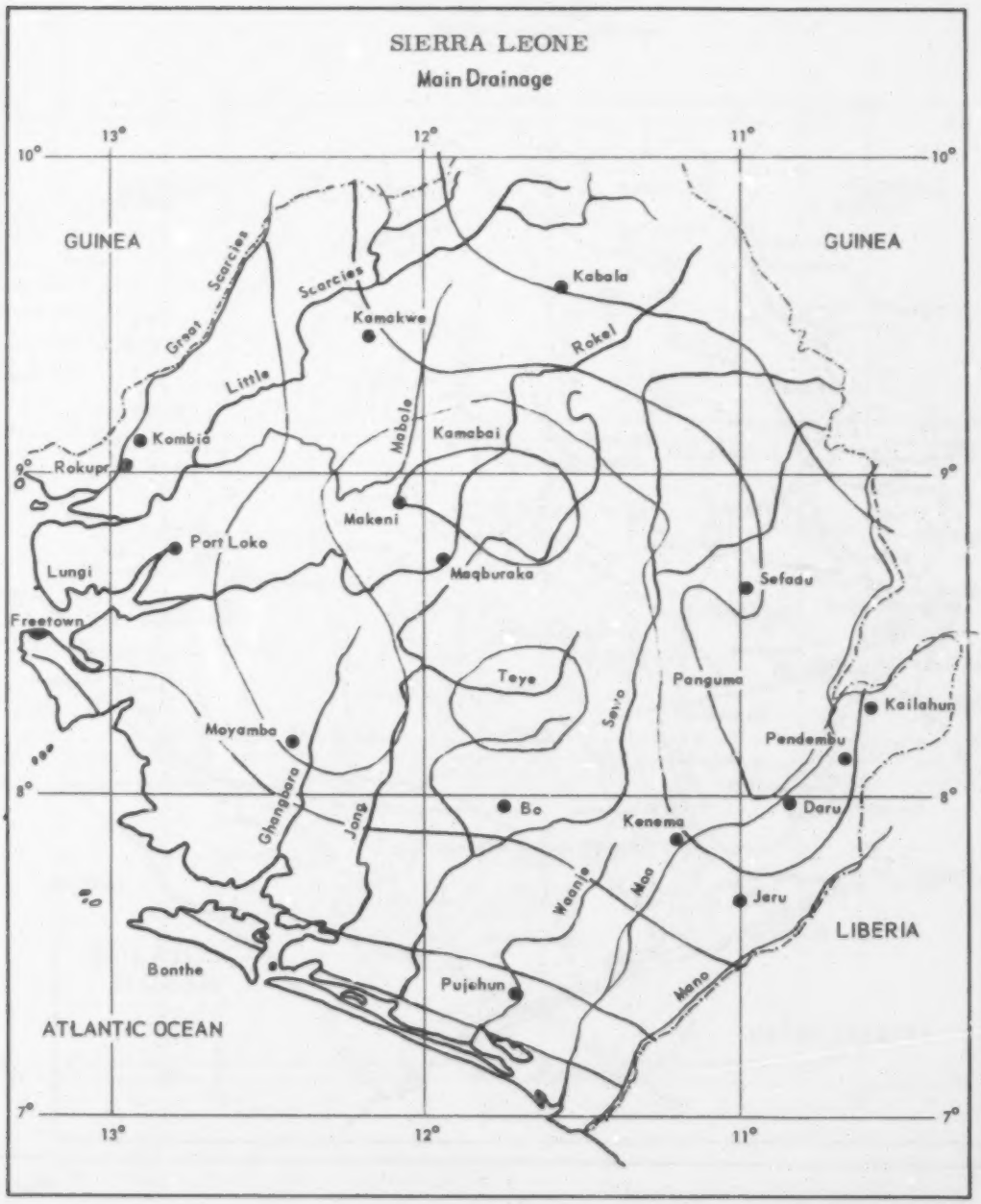
SIERRA LEONE
Main Drainage
13°
12°
11°
10°
9°
8°
7°
GUINEA
GUINEA
LIBERIA
ATLANTIC OCEAN
Great Scarcies
Scarcies
Little
Rokel
Mabole
Kabala
Kamakwe
Kambia
Rokupr
Kamabai
Makeni
Port Loko
Lungi
Freetown
Maqburaka
Sefadu
Teye
Panguma
Sewa
Kailahun
Moyamba
Pendembu
Ghangbara
Jong
Bo
Daru
Kenema
Waanje
Moa
Jeru
Bonthe
Pujehun
Mano

Fig. 3

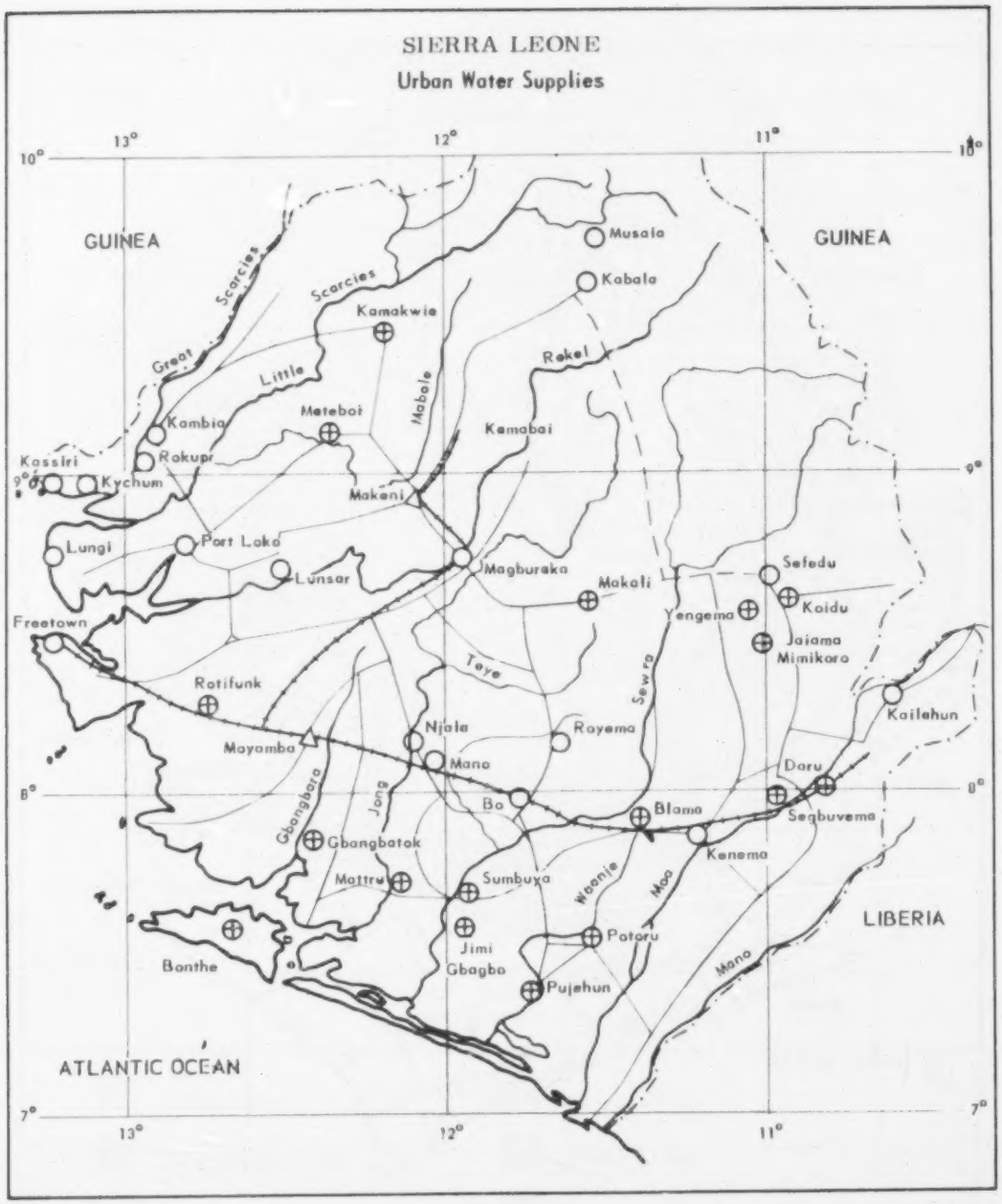


Fig. 4

○ Now Available ⊕ Under Investigation △ Under Construction

Fig. 5

○ Rainfall △ Synoptic ● Climatological

127 E - Oct.1962 - 1,600